Corrosion

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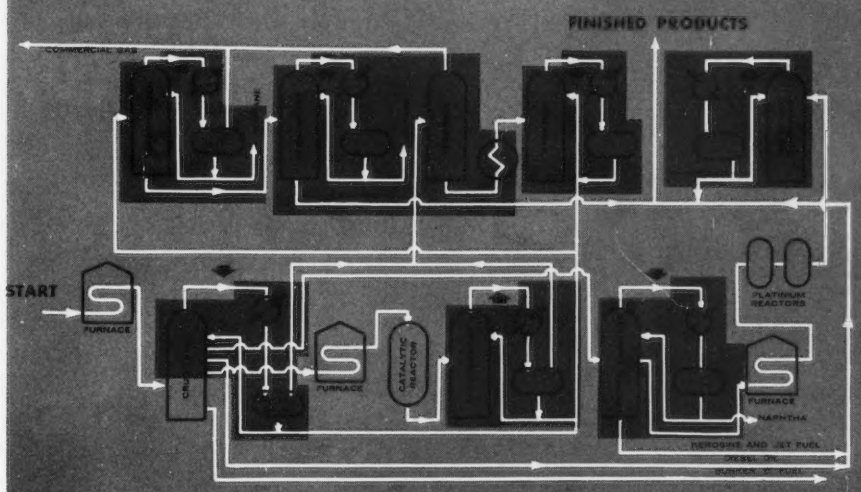
another
TRETOLITE SERVICE
report

Portion of a typical refinery shows some of the areas where KONTOL corrects corrosion and fouling problems (indicated by dark green). Arrows show injection points.



Refiners benefit from 7 advantages of **KONTOL** *Corrosion Inhibitors*

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3. ***Detergent Action.*** KONTOL Corrosion Inhibitor not only protects against corrosive attack but also promotes the high efficiency derived from the operation of clean, non-fouled equipment.

4. ***Product Compatibility.*** So little KONTOL is present that no change in product specifications such as distillation end-point, anti-knock rating, ash, gum formation, etc., can be detected.

5. ***Two-Fold Economy.*** Compared with the cost of using special alloys to combat corrosion, or the cost of replacing non-alloy metals, the cost of KONTOL is negligible. When this advantage is augmented by those gained from a cleaner, more efficient operation, the substantial savings from a KONTOL protection program quickly become apparent.

6. ***Complete Safety.*** KONTOL Corrosion Inhibitor is convenient to handle and easy to use. No special safety precautions are necessary.

7. ***Flexibility in Formulation.*** In order to meet various well conditions KONTOL is available in a wide range of inhibitor formulas. Some are oil-soluble. Some are water-dispersible as well as oil-soluble. Others are water-soluble and oil-insoluble.

A CORROSION RATE SURVEY SERVICE is available to refiners and gasoline plant operators. The Tretolite Company supplies bottles and mailing tubes for submitting water samples for analysis. After analysis, recommendations are made. Tretolite also supplies weighed test coupons which are reweighed after exposure. Corrosion losses are evaluated and recommendations offered. There is no charge or obligation for these services. KR-61-1

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Performance-proven in such corrosive atmospheres as chemical plants, acid tank haulers and marine environments, urethane coatings are now the standard protective finish for the Grumman "Ag-Cat", a custom-designed crop dusting plane.

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C-6

This Month in Corrosion Control . . .

THICK-FILM, solvent-free epoxy coatings have some advantages over solvent dispersed coatings, an article beginning on Page 9 explains. These include lower application costs per mil and greater chemical and corrosion resistance.

INORGANIC ZINC silicate and silicone coatings performed best among several systems tested on a Gulf Coast chemical plant's equipment at temperatures in the 250-1200 F range. Turn to Page 12 for details of 3½ years' tests in this severe environment.

MINE HOIST WIRE ROPE functions in a very corrosive environment. Tests of various materials showed a combination of road construction asphalt, chromate and trichloroethylene gave best results. Turn to Page 22.

FILLED TROWELABLE PLASTIC COATINGS have many advantages. Some of the characteristics of these materials, especially epoxy formulations, are given beginning on Page 28.

HOT-APPLIED WAX TYPE protective coatings for underground pipe lines are covered in an NACE minimum requirements report beginning on Page 117.

PRESSURE-SENSITIVE plastic tapes, prefabricated plastic films to be used with adhesive coatings and extruded plastic coatings for pipelines are covered in NACE tentative recommended specifications. See Page 119.

RUBBER-LININGS useful in aggressive environments are considered at length in a report of NACE Technical Committee Task Group T-6A-1 beginning on Page 121. Included are descriptions, notes on compounding, chemical resistances and other properties. Tabulated are resistances of hard and soft rubber linings to over 200 corrosives. Resistances of butyl, nitrile and chloroprene materials are recorded for comparison.

HYDROGEN EVOLUTION and the volume of steel corroded in both inhibited and uninhibited hydrochloric acid were determined simultaneously in a series of experiments reported in an article on Page 105. DHQ and hexamine used together as an inhibitor were much more effective in reducing hydrogen evolution than was DHQ alone.

GALVANIC CORROSION, that nemesis in many metals designs, has been cited as responsible for shutting down the Freeport, Texas salt water conversion plant after about 60 days' operation. Replacement of about 1700 carbon steel plugs in seven heat exchangers with non-ferrous tubing is expected to take three or four weeks. Low solids water from the plant also is believed to be dissolving scale from distribution lines. Turn to Page 37.

CATHODIC PROTECTION SYSTEM designers need to be aware of the significance of errors in potential measurements related to locations of half-cells. Turn to Page 91 for a discussion of this problem.

EXHAUST GASES containing sulfuric and hydrochloric acid caused rapid corrosion in an ore agglomerating plant. An account of efforts made to define this problem and find solutions, using electrical resistance and coupon testing methods and ultrasonic thickness gauges begins on Page 93.

STRESS CORROSION CRACKING of martensitic stainless steel increases in direct proportion to pH increasing from 3 to 11. Cracking also occurs under anodic and cathodic polarization conditions at pH's to 12.5. Tests on the effect of pH on these phenomena are reported beginning on Page 98.

WELDS of low chromium-molybdenum alloys used in refineries to avoid hydrogen damage fail in service if the chromium and molybdenum content is inadequate. Turn to Page 103.

LPG TANKS in Hawaii, subjected to severe attacks by highly corrosive atmospheres and bright sunshine, are being coated successfully with polyvinylchloride plastisols. The plastisols are being applied in both shop and field. Turn to Page 39.

HAFNIUM's scaling behavior in air between 600 and 1200 C is reported beginning on Page 109.

PIPE-TO-SOIL POTENTIALS can be recorded continuously using equipment described on Page 114. Advantages of getting a graphic recording of potentials keyed to locations on every foot of an underground line are explained. Examples of potential surveys made with the equipment are given.

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Too Little Is Sometimes Too Much

THERE are some occasions when too little is too much; or to go back to an original aphorism: "A little knowledge is a dangerous thing." One of our readers abroad has suggested that a warning is in order to some that the reading of one paragraph of Uhlig's or Evans' book does not make one an expert.

The experienced corrosion engineer can cite instance after instance from his experience when inadequate understanding of the ramifications of a corrosion problem has caused aggravation rather than amelioration of the condition being combated.

Some examples where this has occurred:

Zinc-Coated Steel Hot Water Tanks. There is no question that zinc will protect steel in hot water tanks, when the water is of a certain analysis and/or when the temperature of the water does not go too high. In some cases, when the water is of a certain analysis, temperatures above 140 F will cause the steel to corrode preferentially to protect the zinc. On the other hand, if the analysis of the water is correct and the operating temperature is kept below the required maximum, the zinc will perform its function as desired. These factors must be known, if the application is to be satisfactory.

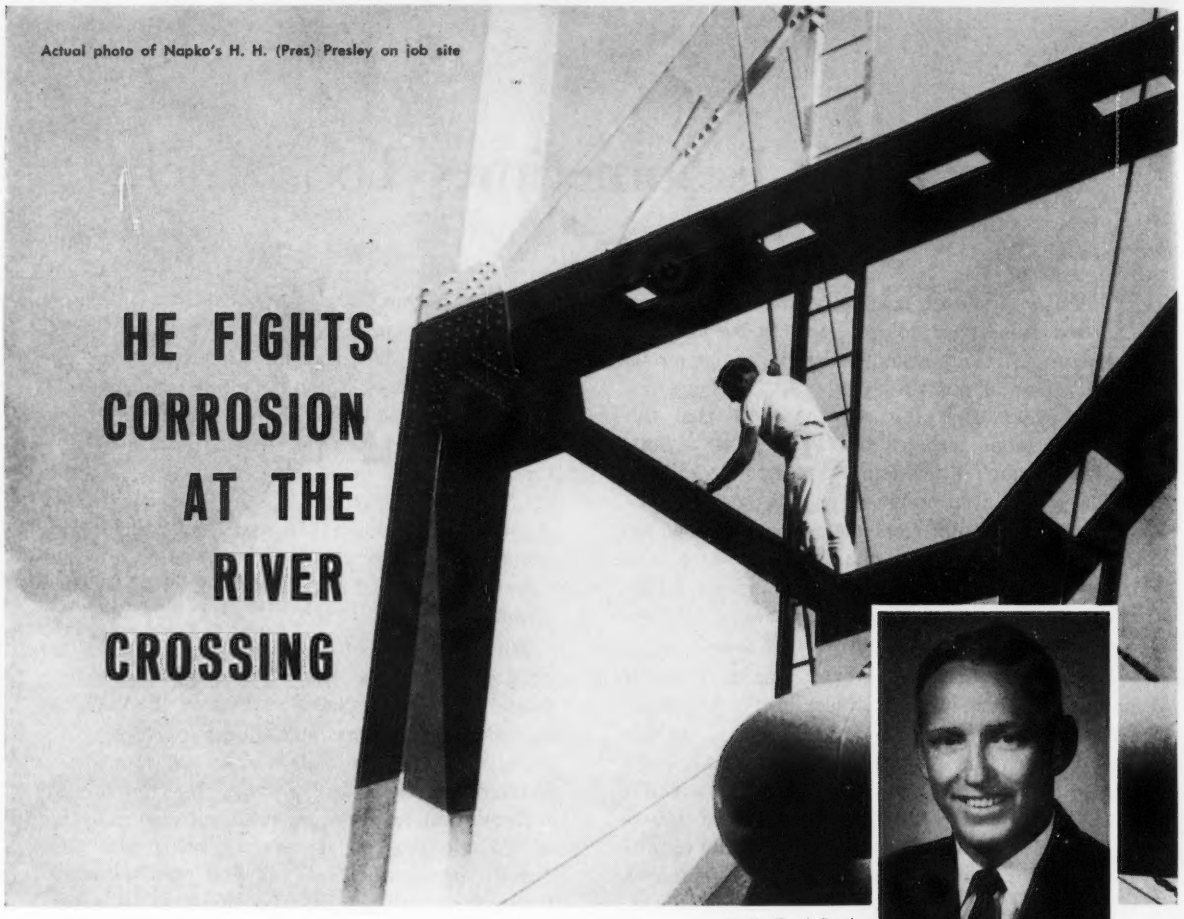
Pickling to Remove Mill Scale. The deleterious galvanic couple between mill scale and the base steel on which it is found is well known. Removal of this scale before coating is considered advantageous, especially when the steel is to be submerged in sea or any other highly ionized water. However, there is a hazard in pickling to remove it: hydrogen embrittlement can occur. While in many cases the hydrogen introduced into the base metal can be removed by standing or immersion in hot water, in some cases the damage it causes is permanent. In this case, in solving one problem, a more serious one may be created.

Tampering With Established Grounds. In our recent series of letters and articles on corrosion by alternating currents, the hazards of tampering with grounds, especially by persons unfamiliar with electrical circuits, has been pointed out. For instance, in attempting to isolate electrically a system of underground water pipes at a home for the purpose of protecting them cathodically, insulators sometimes are installed between the inside and outside piping. When grounds from electrical appliances or motors operating inside the house are connected to the water piping, these insulators eliminate the ground and create a hazardous condition in which fault currents or lightning discharges will find ground otherwise, causing either death or fire. The moral here is: Don't tamper with grounds. Get expert advice before trying to put cathodic protection on your home underground plumbing.

How Much Inhibitor to Use? Because inhibitors are costly there is a tendency to reduce the volume used to the minimum. Furthermore, because the by-products of some inhibitors are toxic, care must be observed in their use. In using an anodic inhibitor, such as a chromate, for example, it is important to have a sufficient concentration of the inhibitor on the surface being protected. Insufficient quantities will accelerate corrosion rather than diminish it. The advice of an expert is required in most cases when inhibition of a liquid system is called for. The problem of inhibition is complicated by many factors, among which might be listed galvanic corrosion, delignification (when wood is present), algae and fungus growth, crevice corrosion, scale and others.

Examples of this kind could be cited by hundreds. They show that it behooves those with authority to seek the advice of their corrosion engineers before making decisions on corrosion control matters. The same man who carefully consults his company's counsel when confronted with a legal problem, often acts on his own knowledge and judgment when trying to solve his corrosion control problems. Those who have no regularly assigned corrosion engineer would do well to use the services of a consultant.

Even when a problem is approached with full awareness of the intricacies involved and when all known contingencies are explored in advance, even the most experienced corrosion worker sometimes makes the wrong decision. Experience, which reduces the probability of error to manageable proportions is valueless unless used.



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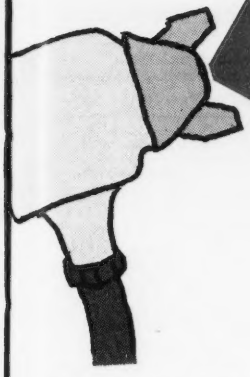

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Jones-Dabney Company
Louisville, Kentucky

TECHNICAL TOPICS

FOCUS ON INDUSTRIAL COATINGS

Pages 9-36

Abstract

Principal advantages of thick-film, solvent-free epoxy coatings are described. The author suggests, because they are not truly volatile-free, that a better term would be "pre-shrunk." Differences are pointed out between the solvent-containing and solvent-free epoxies in application, pot life, film thickness and recoat time. Advantages of the thick-film versus solvent-types are to be found in lower application costs per mil, and greater chemical and corrosion resistance. Comparisons of recent tests in salt fog, are given. Some ways in which adhesion of thick films can be improved are explained. Also claimed are longer film life and lack of shrinkage during curing. Efforts under way to improve performance are described generally. 5.4.5

PRINCIPAL ADVANTAGES of 100 percent non-volatile coatings compared to solvent types are (1) lower application cost per mil of film thickness, (2) greater chemical and corrosion resistance, (3) longer life before refinishing, due to the inherent resistance of epoxy resins and increased film thickness, (4) films stable dimensionally because they contain no unreactive volatiles and (5) relatively low fire hazard (no solvent).

Although they are sometimes called 100 percent solids coatings, solvent-free coatings, or 100 percent non-volatile coatings among other names, none of these designations accurately describes the product. This is true because in many cases there will be present a volatile material which may be a curing agent, such as an aliphatic amine, or a reactive diluent, such as a glycidyl ether which reduces greatly the viscosity of the system but which enters into the reaction and becomes a part of the film. There may be a small amount of a solvent added to the system as an activator for an anti-sag agent.

For these reasons, a better descriptive name for these coatings needs to be developed. One such name is "pre-shrunk." This is appropriate because, despite the presence of reactive volatile materials or of extremely small quantities of solvents, these coatings can be expected to produce films with very little dimensional change from the uncured to the cured state.

Application Differences Noted

The usual solvent type converted epoxy coating, as applied, will contain roughly from 50 to 70 percent volatile solvents by volume depending on how heavily it is pigmented. This relatively large volume of volatiles greatly influences film formation and performance of epoxy coatings. The five principal factors are given below.

1. **Application.** Techniques used in applying a coating onto a substrate play an important role in its film properties. Some of the usual application techniques and equipment used in applying solvent system coatings must be modified considerably when a solvent-free system is to be applied.

Mixing the epoxy finish and the curing agent becomes much more complex, for example. Viscosity of the mixture and lack of volatile materials increases the work required in the mixing operation and at the same time tends to increase the amount of entrapped air and to hold that air more firmly in the mixture. The amount of entrapped air must be minimized if a good film is to be obtained.

Application equipment must be such that the coating is applied rapidly and

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★ A revision of the paper titled "Pre-Shrunk Films—Those Remarkable Epoxies Again," presented at a meeting of the Northeast Region, National Association of Corrosion Engineers, Huntington, W. Va., October 11-14, 1960.

Pre-Shrunk Epoxy Coatings

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evenly and must be capable of readily handling the high viscosity, thixotropic coatings. In both mixing and application, speed is essential because of the short pot life of epoxy-curing agent mixtures.

2. **Pot Life.** Because there are no solvents, the reacting materials are closer together, thus the pot life of the mixture is shortened considerably. For example, a solvent-containing epoxy coating cured with TEPA (tetraethylene-pentamine) will have a pot life of 8 to 12 hours at normal temperatures. A solvent-free system also cured with TEPA, started at room temperature in a mass of only a quarter pint, has a pot life of less than ½ hour. Other curing agents give longer pot life.

3. **Temperature.** Pot life is greatly influenced by temperature. Below room temperatures, the reaction between epoxy resin and converter slows and pot life lengthens. At higher temperatures, pot life is shortened. Because the reaction tends to be exothermic, pot life is even shorter if the mass of the mixture is very large because of the more rapid increase in temperature. By controlling temperature, the pot life and curing rate can be increased or decreased because the curing rate usually is directly proportional to pot life.

4. **Curing Agent.** Because this discussion is limited to epoxies as coatings for room temperature conversion, the number of curing agents suitable is reduced. Many curing agents, such as the anhydrides, the polyfunctional acids and most of the aromatic polyamines are ruled out for room temperature use. They certainly should be considered, however, where supplementary heating is available.

Most of the amine curing agents suitable for room temperature curing applications are based on polyamines such as diethylene triamine (DTA), triethylene tetramine (TETA) and tetraethylene pentamine (TEPA) and various modifications and derivatives of these amines. Some common modifications and derivatives include the reaction with epoxy compounds to form less volatile adducts and with various carboxylic acids to form amido amines which can be used to impart varying degrees of flexibility to the cured coating.

No general recommendation for an optimum curing agent can be made because the choice depends on the end use of the coating. For resistance to chemicals, the preferred choice would be a polyamine or a polyamine adduct. For film flexibility, the preferred choice would be one of the amido amine curing agents. The choice is more complex than indicated because the various agents produce wide variations in pot life when mixed with epoxies for solvent-free coatings. All polyamines and polyamine adducts tend to give short pot life, amido amines give longer pot life varying with the specific amido amine used. Compromise often is necessary on the desired film properties due to application method or equipment that must be used, which may make pot life the most important single factor to be considered.

TABLE 1—Acid-Resistant Thick-Film, Solvent-Free Epoxies vs Solvent-Type

Coating			Acid Immersion (180 to 200 F)	
Type*	First (mils)	Second (mils)	40 Percent Sulfuric	40 Percent Hydrochloric
1	25		48 hr, OK Slight discoloration	48 hr, OK Slight discoloration
2	1	2	<8 hr, Failed by blistering	<16 hr, Failed by blistering

* Type 1—Solvent-Free. Type 2—Solvent-Type.

5. **Film Thickness and Recoat Time.** Neither film thickness per coat nor recoat time are problems in film formation with "pre-shrunk" coatings. One of the advantages is the unusually heavy film that can be deposited in one application with improved chemical and corrosion resistance and film life.

Properties of Solvent-Free Coatings

Some important advantages of solvent-free coatings will now be discussed in more detail with a few graphic illustrations from various tests to give a better indication of what can be expected from them.

1. Lower application cost per mil of coating applied. In epoxies, as with other coatings, labor and equipment represent the major portion of finishing costs while the actual paint cost is the minor portion.

Application of films of two to three or more times the usual thickness in one operation is highly desirable. These heavier films, possible with 100 percent solids epoxies, cost more for material but only slightly more for application than the solvent-type epoxy. The result is that the cost per mil of coating is less.

Solvent system finishes cannot be applied in thick coatings because of solvent entrapment. This entrapment results in wrinkling, cracking, poor through-dry or through-cure and the like. Properly formulated coatings of the "pre-shrunk" type can be applied in heavy films without showing these defects. Thus a coating of 20 mils or more in one application becomes practical. A film of like thickness using a solvent-type coating requires eight or ten applications with correspondingly higher application cost and loss in time due to necessary curing between coats.

2. Greater chemical and corrosion resistance. The excellent chemical resistance of heavy films can best be demonstrated by test results shown in Table 1, where a 25-mil "pre-shrunk" coating is compared to a typical 3-mil, 2-coat solvent system epoxy coating. The "pre-shrunk" epoxy coating shows no signs of failure other than some discoloration after 48 hours' exposure to 40 percent hydrochloric acid solution and 40 percent sulfuric acid solution at 180 to 200 F. In the same test, the solvent system failed by serious blistering in less than 8 hours in the sulfuric solution and less than 16 hours in the hydrochloric solution.

Results of another series is shown in Table 2. Here the improved resistance to nitric acid and to hydrochloric acid of the 20-mil solvent-free films is evident. Finishes are the same as those in the previous tests except that the topcoat is the same throughout and the "pre-shrunk" epoxy coating was used as a heavy duty primer.

Improved Adhesion Developed

In a recent corrosion test, two panels of a solvent-free gray epoxy enamel were prepared. One panel was scribed with an X, the other was not, and both were exposed to 20 percent salt fog. In 200 hours the scribed panel showed considerable peeling back from the scribe marks (as much as ¾ inch) accompanied by appreciable rust formation. The other panel, after 1000 hours, was in excellent condition with only a few localized blister areas. When the paint film was removed, the blister areas showed no under-film corrosion.

This tendency to peel when the film is ruptured is due to the somewhat

TABLE 2—Acid Resistant Epoxy Coatings vs Solvent Types

Coating System*	Film Thickness (mils)	10 Percent Acid	Hours		Days		
			24	120	7	20	30
1.....	20	HAc	OK	Slight blisters	Same	Same	Same
2.....	3.5	HAc	OK	Slight blisters	Same	Same	Same
1.....	20	HNO_3	OK	OK	OK	OK	Small blisters
2.....	3.5	HNO_3	Discolor	Fail	.....	.....	.....
1.....	20	HCL	OK	OK	OK	OK	OK
2.....	3.5	HCL	OK	OK	Small blisters	Fail	.....
1.....	20	H_2SO_4	OK	OK	OK	OK	Blisters
2.....	3.5	H_2SO_4	OK	OK	OK	OK	Blisters

* System 1—Solvent-free. System 2—Solvent-type.

poorer adhesion of solvent-free epoxy coatings in heavy films over a sealed substrate. This is probably due, at least in part, to the cohesion of the epoxy molecules and the rigidity found in thick films. These combined forces apparently are stronger than the adhesive forces holding the film to the substrate. This effect is not pronounced on porous substrates where penetration of the film improves adhesion. This effect is much less prevalent on sandblasted steel where the roughness of the substrate gives some degree of mechanical bond.

Because this loss of adhesion could be a serious deficiency, a series of tests was conducted to seek improvements. A one mil solvent type epoxy primer of the zinc chromate-iron oxide type and one of the lead silico chromate type were tried, both cured with TEPA. After 40 hours, an 18 to 20 mil film of solvent-free epoxy coating was applied. Duplicate panels were made, one of each being scribed with an X, the alternates remaining unscribed. After 1000 hours' exposure to 20 percent salt fog, the panels were in almost perfect condition whether scribed or not. There was no blistering at the scribe marks and no under-film corrosion.

A solvent system epoxy enamel when applied to the same primers in a normal 2 to 2½ mil film thickness and given the same 1000-hour exposure to 20 percent salt fog has not performed as well. The scribed panels show slight blistering extending as far as 1/16 inch from the scribe marks. Though these panels will run at least several hundred hours more before the test is considered finished, it is apparent that the "pre-shrunk" coatings are performing better.

3. Longer film life. Thick, solvent-free coatings increase the interval between repaintings 3 to 5 times. Typical example of improved service life is that of a previously painted concrete floor of a men's washroom in a laboratory building used daily by approximately 30 men. A heavy film of solvent-free green epoxy was applied at an estimated film thickness of 1/64 inch (15 mils) three years ago. This coating had a useable pot life of 30 minutes in half gallon quantities.

The film is still in excellent condition, showing such little wear that it is expected to last at least another 8 to 10 years. This would be up to 15 times longer than would be expected from a usual floor paint and approximately 8 to 10 times longer than can be expected from the usual solvent system one coat pure epoxy floor paint.

4. Film is "pre-shrunk." Because the film contains active ingredients (plus at times some) non-reactive, non-volatile diluents, there is little (if any) loss in volume from the time the film is applied until it is cured completely. Heavy films of other coatings that do not have this property tend to skin dry or surface cure, thereby giving poor through-dry or poor through-cure. Wrinkling, alligatoring or possibly cracking may occur as the film shrinks, or many such film irregularities may become evident, so that the advantages expected from a thick film are lost.

Future of "Pre-Shrunk" Solvent-Free Coatings

The smooth, glass-like surface of solvent-free epoxies, coupled with their high degree of chemical resistance, will induce a growing number of paint formulators, faced with problems for which these coatings seem well fitted, to turn to them for a solution.

Investigations aimed at solving limited adhesion and improving application techniques continue. A third problem facing those using solvent-free coatings, (partially solved by inclusion of active diluents, such as the glycidyl ethers, or viscosity reducing curing agents) is high viscosity. The ideal solution would be a diluent, either active or not, but at least with relatively high chemical resistance, which would greatly reduce the viscosity of the mixture, thereby adding greatly to application ease.

A reactive diluent has an inherent advantage in that it would rapidly increase in viscosity as it cured, thereby permitting application of heavy films without as much danger of sagging as would be likely with a non-reactive one.

More effective puffing or anti-sag agents are desirable as an aid in building satisfactory heavy coatings. Improved mixing and application equipment, including guns, roller applicators and uniform feeding spreaders are being sought to give the user better control.

DISCUSSIONS

Question by William F. Chandler, Porter Paint Co., Louisville, Kentucky:

You made the statement that it takes 10 mils of 100 percent pre-shrunk epoxy to equal resistance of 5 mils of solvent system. Why is this? You say the higher molecular weight, solvent cut type has better resistance properties than lower molecular weight, 100 percent solids type, but other experts say the liquid, lower molecular weight, higher cross linked type has better resistance properties. There is much confusion about resistance properties of liquid epoxies as compared to the solvent cut type. There is certainly no unanimity of opinion in this field.

Reply by R. G. Fortener:

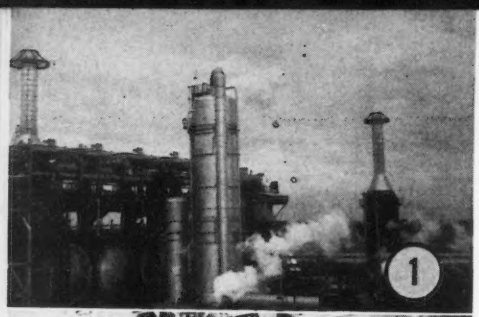
All of our tests have shown that as the melting point of the epoxy resins increases, indicating increased polymer size, the chemical resistance increases. Published reports of other investigators bear out these same results. These results are based, however, on equal film thicknesses. As was mentioned earlier, the lower melting or liquid epoxy resins can be used in 100 percent solid coatings to provide very heavy films in one coat while the solutions of the higher melting point epoxies cannot. Therefore, when compared at the optimum practical film thicknesses possible with each type, the many times thicker liquid epoxy films will definitely give better chemical resistance. It is the film thickness that makes all the difference.

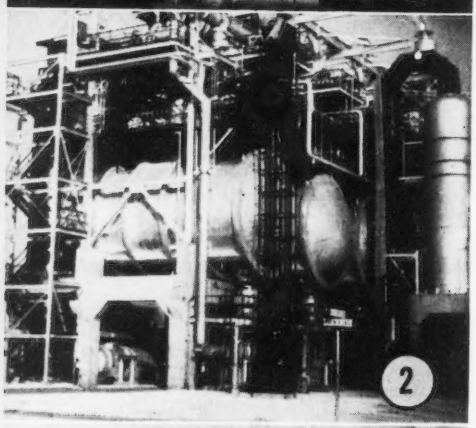
Question by John J. Oates, Subox, Inc., Hackensack, New Jersey:

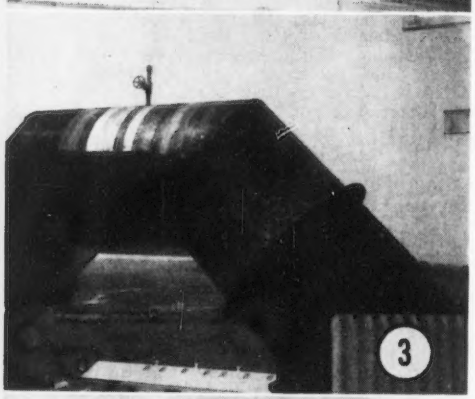
Would you care to generalize on the dry film thickness of a pre-shrunk epoxy coating required to perform as effectively as a 5-mil epoxy system deposited as a conventional solvent based coating?

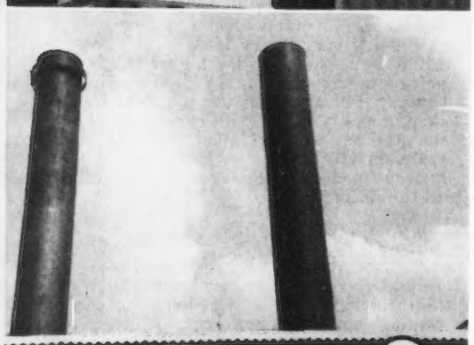
Reply by R. G. Fortener:

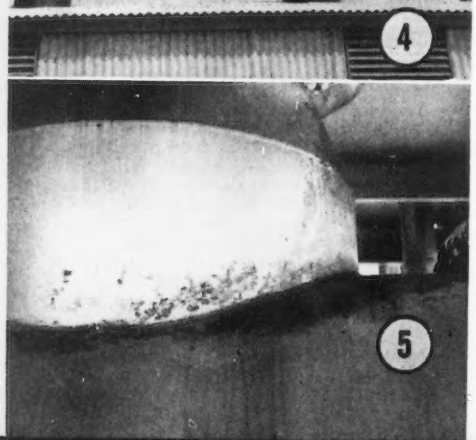
We have tested films of the two types at equal film thickness, and we have tested them at the optimum practical film thicknesses possible with each, which would be many times thicker films of the pre-shrunk type as compared to the solvent based type. We have not, to my knowledge, run a ladder to determine exactly what film thicknesses the two types give equal chemical resistance. As a pure guess, we would say that the so-called pre-shrunk type would have to be approximately twice the film thickness of the solvent type, that is, 10 mils versus 5 mils.











Coating Systems f

Abstract

A report is given on tests over a period of 3½ years at a Gulf Coast petrochemical plant to find coatings suitable for steel process vessels, piping and equipment operating in the range of 250-1200 F. Plant operation schedules frequently prevented proper application and curing. Coatings tested included silicones, aluminum coated steel, aluminum sheathing, alkyds, zinc rich organics, catalyzed epoxy, air drying phenolics, inorganic zinc silicates and others.

Tests showed best results were achieved using inorganic zinc silicate primers with various topcoats of other materials. Best among these were the inorganic zinc silicate/silicone topcoat and inorganic zinc silicate/inorganic silicate pigmented with zinc oxide systems. Conspicuous differences were noted in performance between surfaces sandblasted with large and small size grit. 5.4.8, 5.4.2

BECAUSE ADEQUATE protection of high temperature surfaces is a major problem and is especially serious in the Gulf Coast area from corrosion as well as metal preservation standpoints, Firestone Tire and Rubber Company decided that efforts should be made to evaluate organic coatings for such service at its Orange, Texas plant. This evaluation was difficult because of the conditions under which the tests were conducted. These are particularly unsatisfactory in a petrochemical plant where economics often prohibit a unit shutdown. This prevents proper evaluation under recommended procedures and time limitations do not permit the proper conditioning (or cure) of organic coatings. This time problem compelled an investigation of other methods that would permit deviations from procedures recommended for high temperature surfaces.

This report attempts to show that, although all organic coatings for high temperature surfaces tested were not conditioned as recommended by their manufacturers, deviation from normal procedures did not necessarily result in poor service. In some instances deviations produced performances superior to those obtained when the manufacturers' recommendations were followed as closely as operating conditions would allow.

Also, one case shows that the inability of these organic coatings to perform as promised is sometimes helpful: Because of coating deterioration at high temperature, breaks in refractory linings can be detected easily.

Silicone Coating Tested

High temperature coatings usually include silicone resins. Attempts were made to evaluate the ability of these coatings to adhere securely to surfaces prepared by wire brushing. Evaluation also was made of the claim that these products will "fuse" with the metal to which they are applied to form a hard, elastic coating. Most silicone resins are recommended for use in the 450 to 1700 F range, and it is reported that they can withstand extreme temperature changes and protect the substrate from underfilm corrosion.

Tests were started approximately three and one-half years ago on the hot surfaces of a butadiene plant to evaluate a variety of recommended products and to beautify the plant. The plant is located approximately 20 miles from the Gulf of Mexico where the climate is characterized by heavy rainfall, high mean relative humidity and an abundance of bright sunlight. The unit charges normal butane-butylene to reactors containing a Houdry catalyst operating in the temperature range of 1000 to 1200 F. Due to the high reaction temperatures, the unit includes hundreds of feet of piping operating at temperatures from 250 to 1200 F. These surfaces, furnace stacks and exteriors of package boilers produc-

Figure 1—Stacks of vertically fired furnaces sheathed with aluminum corroded when water reached the steel during shutdowns. Figure 2—Process lines covered with aluminized steel corroded when water reached the steel during shutdown. Figure 3—Coatings were screened on exterior surfaces of process lines. Figure 4—Stack blasted with heavy grit (left) showed coating failure quicker than stack blasted with lighter grit (right). Figure 5—Silicones' failure indicated break in refractory linings.

ms for Steel at 250 to 1200 F★

Gatewood Norman
Firestone Tire & Rubber Company
Orange, Texas

ing process steam, provide an ideal test area for evaluating high temperature coatings. The elevated temperatures prevent atmospheric corrosion becoming a problem on most of the hot process piping except when the unit is shut down and surface temperatures drop below the dew point. On the other hand, prevalence of surfaces operating at high temperatures makes it virtually impossible to keep the plant well painted and attractive without using finishes which will withstand the temperatures.

Various Alternatives Tried

After repeated failures of high temperature silicone paints, management investigated the use of aluminum coated steel and aluminum sheathing. Applications were made to stacks on vertically fired furnaces and a hot process line. (Figures 1 and 2) While this procedure produced the desired esthetic effect, it did not give the best solution from an engineering point of view because the sheathing not only did not prevent water from reaching the steel substrate during shutdowns, but also tended to hold water against the surface to aggravate corrosion and prevent close inspection.

Initial screening of coatings recommended for high temperature service was done on the exterior of hot process lines from the reactors. (see Figure 3.) These lines are exposed to the weather and operate at approximately 900 F.

Initially, surface preparation was limited to hand cleaning by power wire brush and disc sanders. Irrespective of the material applied, all organics showed definite signs of failure within three months.

Sand Size Differences Probed

Subsequently, tests were run using sandblasted surfaces, and an effort was made to evaluate the effect of difference in sandblasting grit size. One test in this series involved twin boiler stacks which operate at 400 F. One was sandblasted to white metal using silica sand screening 16 to 30 mesh while an adjacent unit also was sandblasted to bright metal using a grit of 80 to 120 mesh. In both cases, coating was applied immediately on completion of the surface preparation step and conforming to the procedure recommended by the manufacturer.

The silicone coating used on both stacks, was selected from those passing preliminary screening tests on surfaces operating at 750 F.

In less than six months, the coating applied over surfaces prepared with the heavier grit began to break down with general failure in the

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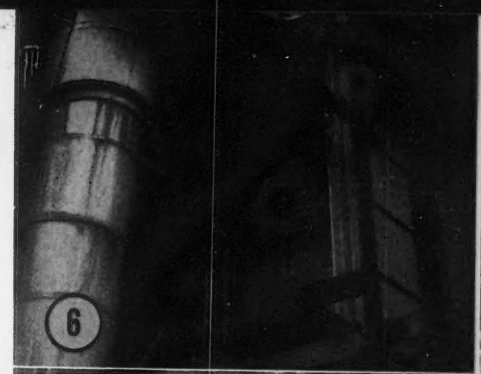
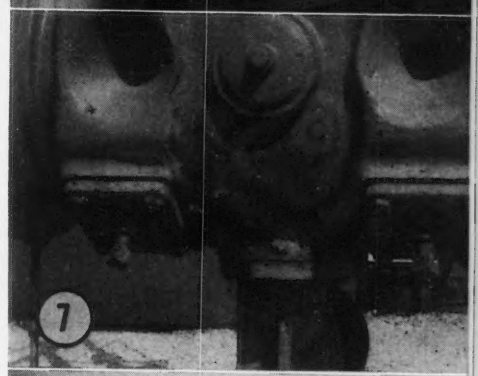
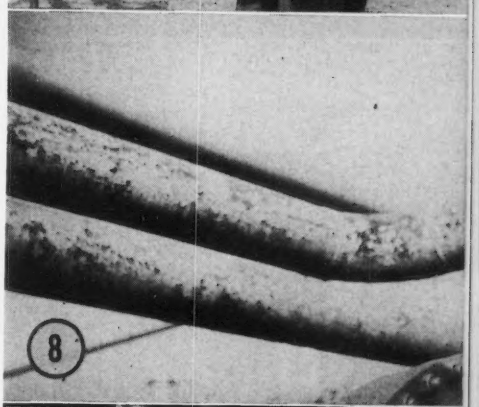
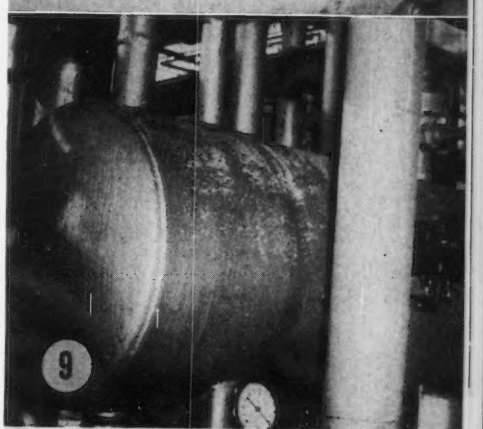
★ Revision of a paper titled "Protective Coatings for High Temperature Service" presented at the 17th Annual Conference, National Association of Corrosion Engineers, March 13-17, 1961, Buffalo, N. Y.









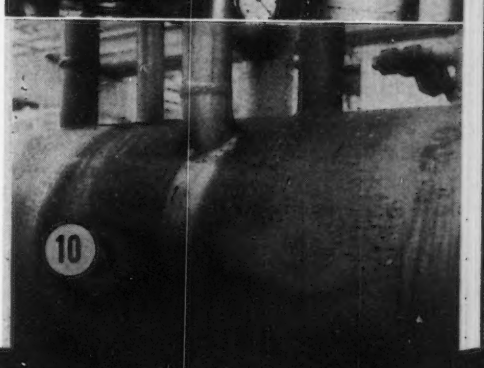
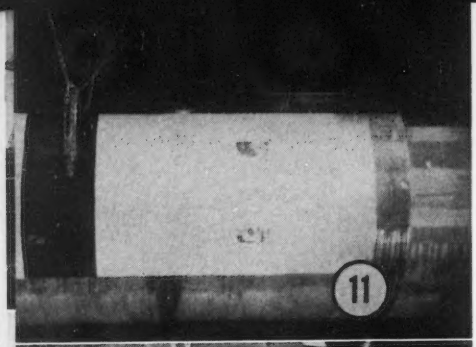
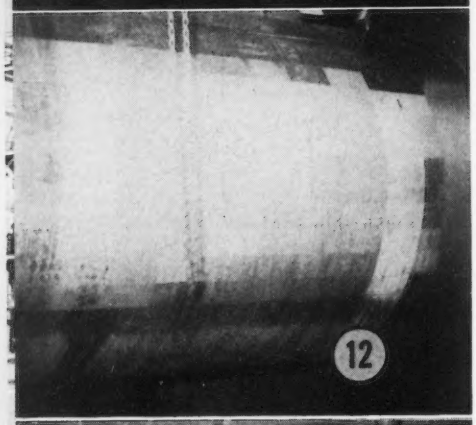
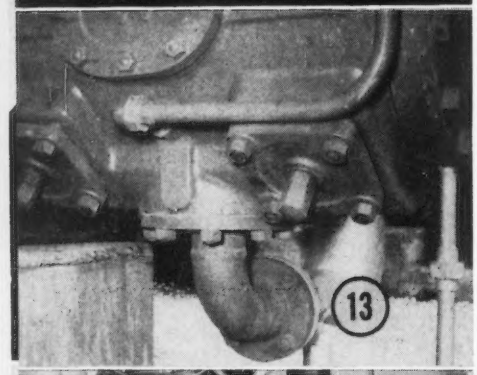
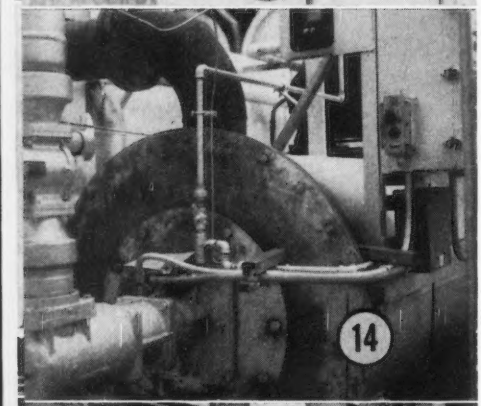


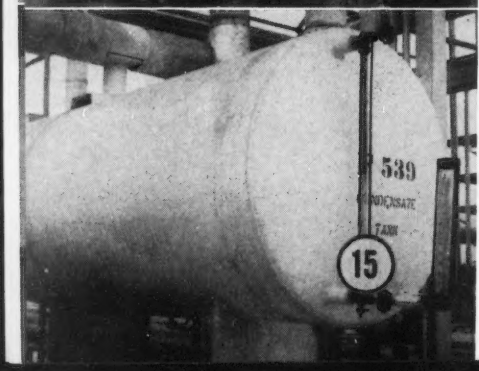
Figure 6—Failures of silicones at temperature about 450 F (scaled surface) reveal refractory lining failure. Figure 7—Alkyds failed on compressor cylinder discharge ports in one to two months. Figure 8—Pinpoint failure of zinc rich organic coatings is seen in six months. Figure 9—Example of failure of catalyzed epoxies and air drying phenolic systems on steam condensate tank at 250 F. Figure 10—Another example of catalyzed epoxy and phenolic system failure on 250 F steam condensate tank.











Coating Systems for Steel

(Continued From Page 13)

weld areas. (Figure 4) Similar tests run using a variety of proprietary products containing silicones mixed with other resins and in all cases results have been comparable. These tests indicate that some manufacturers do not specify the same thorough surface preparation for their products as is commonly recommended by those selling vinyls, epoxies, phenolics, and other specialized materials for extreme services.

All tests in Firestone's plant show that sandblasting is mandatory to achieve reasonable life expectancy and that fine grits of the size indicated should be used. While the stacks pictured were in good condition after nine months of service, experience indicates that even with the closest attention to all details, including surface preparation, a life expectancy greater than two years cannot be expected from the silicones in this service at 600 F.

Some 30 silicone coatings included in the high temperature screening tests all gave disappointing results. One side benefit used to advantage in indicating breaks in refractory linings and thereby expedite repair during plant shutdown. Figure 5 shows an area revealed by failure of a silicone on the exterior of a 48-inch process line. While this silicone was rated by its manufacturer as being suitable for temperatures beyond the 1000 F range, the skin temperature of the line was 800 F. Experience has shown the silicones immediately fail at points where holidays develop in the refractory lining. The same phenomenon has been noticed even at lower temperatures as illustrated in Figure 6 by failure of materials on the boiler exterior where skin temperatures in the order of 450 F are common. To produce indications of this kind, it is an advantage to use material somewhat inferior to the manufacturer's claims. The failure or "tattle-tale" feature forms a useful economic function.

Coatings In Lower Temperatures

While the high temperature tests were in progress, a very extensive test was underway to find coatings suitable for 250 to 350 F. Many manufacturers of alkyd, phenolic aluminum, zinc-rich organic and epoxy coatings claimed that their products would provide very good protection for surfaces operating in this range. Almost all tests were conducted on the exteriors of high pressure compressor cylinders, compressor discharge piping and steam condensate tanks.

Average life expectancy of recommended alkyds on compressor cylinder discharge ports was about one to two months. (Figure 7) A number of zinc-rich organic coatings tested over bright metal blasting both alone and overcoated with phenolic aluminum topcoatings showed pinpoint failure within six months. (Figure 8)

Tests were run later on steel surfaces and piping adjacent to cooling towers. Results with the zinc filled organics were disappointing and gave reason to question the merit of this class of materials for any service in a humid area.

Little Evidence of Cathodic Protection

It is claimed that these products offer some cathodic protection from the zinc in the coating. In all tests so far, there has been very little evidence of cathodic protection, and there have been some cases where

(Continued on Page 16)

Figure 11—How topcoats were tested over inorganic zinc silicate primers. Figure 12—Results of test in Figure 11 after two years' exposure. Figure 13—Alkyds perform well as topcoats over inorganic zinc silicate primers. Figure 14—Showing adhesion failure of topcoat when inorganic zinc primer was heated over 300 F before application of topcoat. Figure 15—Inorganic primer/inorganic silicate pigmented with zinc oxide topcoat systems perform well but are sensitive to intercoat contamination.

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Inorganic Zinc Silicates Tested

(Continued From Page 14)

the opposite effect seemed to occur, that is, corrosion seemed to have been accelerated at the bare spots. The use of zinc as a pigment should not be expected to produce miraculous results. Generally, these materials were completely inadequate and inferior in every way to well formulated vinyl, epoxy or chlorinated rubber coatings.

Other Organics Tested

Many manufacturers recommend catalyzed epoxy and air drying phenolic coating systems for protection of surfaces operating in the 350 F range. As sites for evaluation of these materials, steam condensate tanks common in butadiene plants were selected. In all cases, surfaces were sandblasted to white metal; prime coats were applied by brush, topcoats by spray, to surfaces at atmospheric temperature. No satisfactory organic product was found. These materials seem to be particularly susceptible to failure from accelerated chalking, brittleness and spills of hot condensate. (Figures 9 and 10)

At the time the reported testing was in progress, virtually all maintenance coating work in the plant was being done with inorganic zinc silicate coatings which have proved so popular in the Gulf Coast areas as permanent primers. Performance of these materials was as outstandingly good as that of the silicones was bad. Despite the cautions voiced by all manufacturers, it was decided to make a series of high temperature tests using inorganic zinc silicate coatings as permanent primers on a process line which operates at temperatures varying from 800 F to 1000 F.

Primers Prove Beneficial

Test areas prepared by sandblasting received one coat of inorganic zinc silicate primer each followed by twelve different silicone topcoatings proved best in preliminary screening. (See Figure 11.) As a control, adjacent areas were primed with a variety of the better high temperature silicone coatings. After two years' exposure, ten of the silicones applied over the inorganic zinc silicate primer were still intact where the same silicone systems failed in a few weeks when applied directly to the metal in multiple coats. (See Figure 12)

Performance of the silicate was surprising considering that the line operates some 400 F above the temperature limitation of the inorganic zinc silicates and averages some 220 F above the melting point of zinc, which is their pigment.

The literature is full of references saying flame-sprayed metal coatings operate well at high temperatures due to the production of oxides in the brief period while the molten metal is transversing the short distance from the metallizing gun to the surface being coated. Excellent performance of inorganic zinc silicate coating in this instance could not be explained in this manner because the materials were applied cold and topcoated with silicones immediately after application and before the film was heated. According to F. N. Speller, the only rational explanation for the excellent service seems to be that some of the zinc loading of such coatings alloys with the mild steel substrate. After the inorganic zinc silicates success in this test, they were applied to a variety of field units ranging from compressor cylinders to stacks and breeching.

In the case of the compressor cylinders, it was found that alkyds, which failed in one or two months when applied directly to sandblasted surfaces, showed no tendency to fail when applied over an inorganic primer. (Figure 13.)

Stacks and breeching which operate at 600 F were sandblasted to white metal and primed with an inorganic zinc. After the curing solution residue was removed, one coat of a silicone coating was applied. Because the plant resumed operations application of the second coat of high heat silicone was delayed a month. This system is performing extremely well after 15 months of service, and even under the most minute examination it shows no tendency to fail.

In many cases, attempts were made to coat equipment during plant shutdowns when there was insufficient time to apply more than the inorganic zinc primer. During subsequent shutdowns, attempts then were made to overcoat the primed surfaces with a variety of topcoats ranging from alkyds to silicones and including inorganic white topcoats. In every case where surfaces primed with the inorganic zinc silicate coating had been exposed to temperatures in excess of 300 F, it was found impossible to get the topcoat to adhere. (Figure 14) This may be explained by the formation of zinc oxide on the surface of the heated film, or possibly by accumulation of basic zinc carbonate.

Another System Succeeds

In addition to the inorganic zinc primer/silicone topcoat system, one other extremely attractive coating system with unusual merit was discovered for high temperature service. This consisted of one coat of inorganic zinc silicate prime, topcoated with one coat of an inorganic silicate coating pigmented with zinc oxide. Films of this type have performed extremely well on stacks operating at temperatures in excess of 600 F, as well as on the exteriors of hot condensate tanks and are unrivaled in beauty and should find very widespread application once the formulators discover some way to diminish the sensitivity of the white topcoating to intercoat contamination. (Figure 15.) Even the most minute amount of curing solu-

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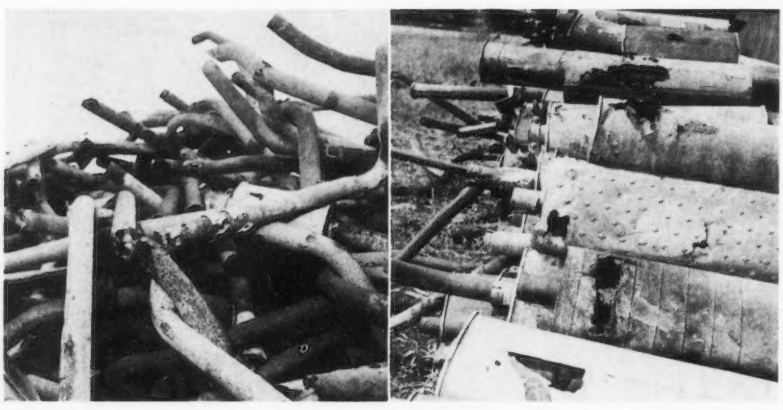

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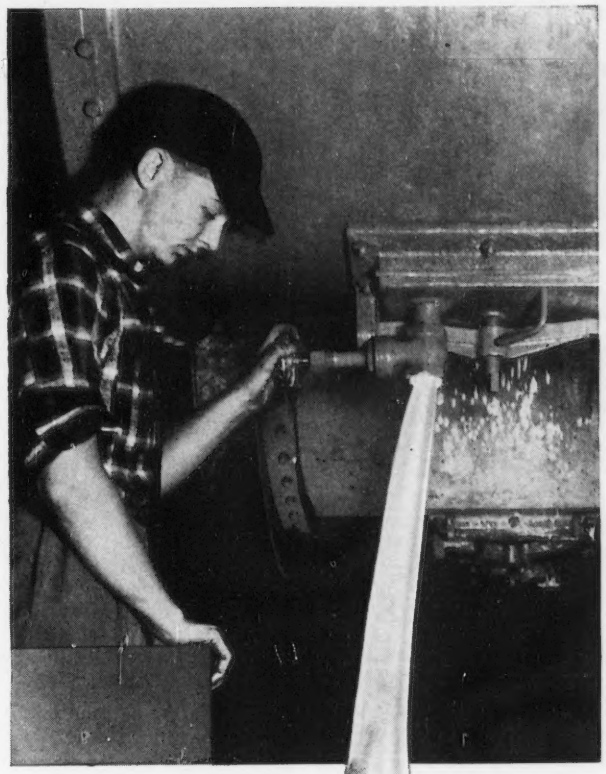
A staff feature is scheduled in the October issue on the devastating corrosion loss in auto exhaust systems. Causes of this corrosion damage will be discussed with materials being used to minimize this corrosion loss.

Muffler design problems in relation to corrosion and materials being used for corrosion control also are discussed. Materials included are zinc coated steel, aluminized steel, ceramic coated steel, chromium rich diffusion coatings on steel and a new stainless steel specially designed for auto muffler fabrication.



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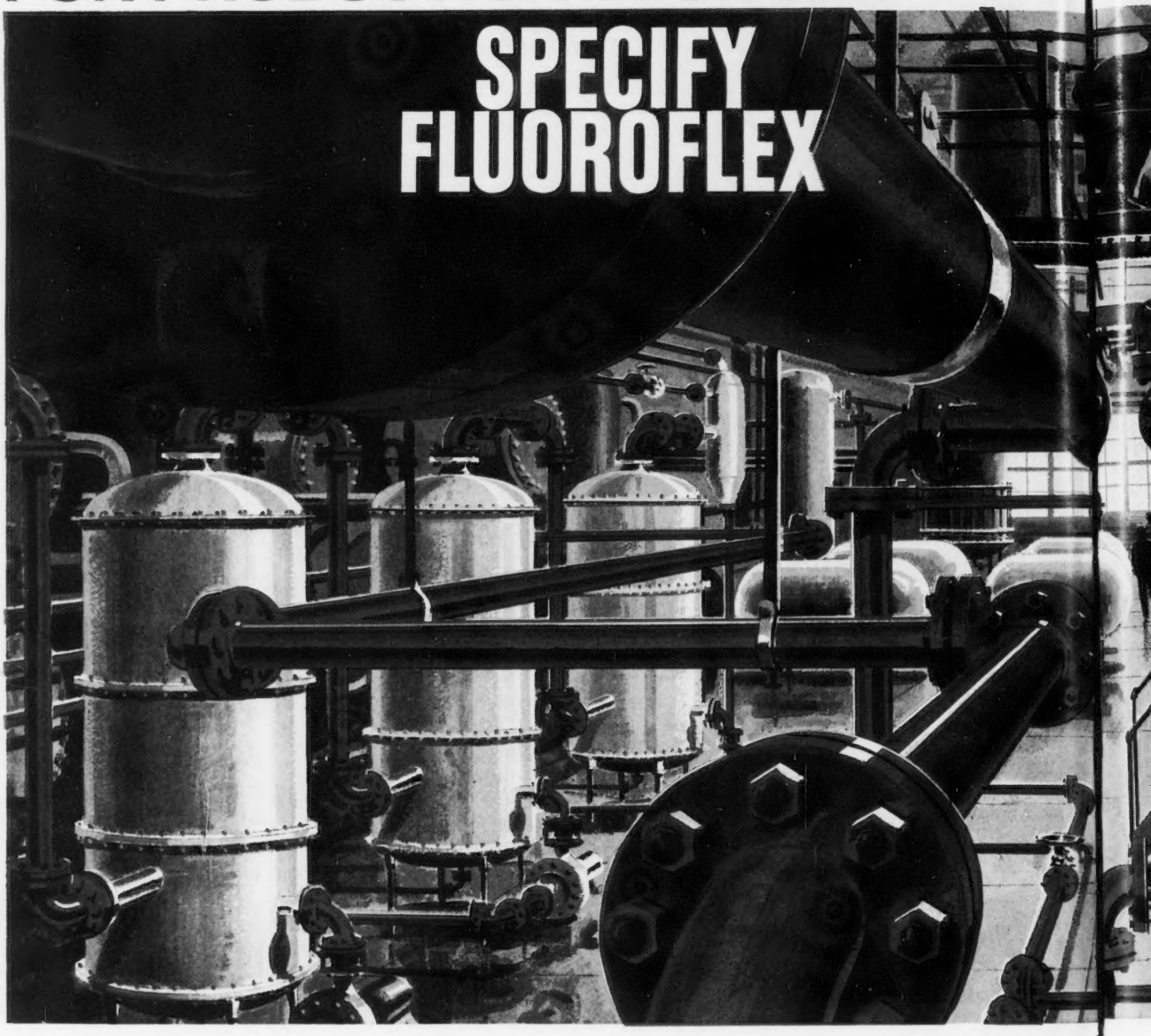

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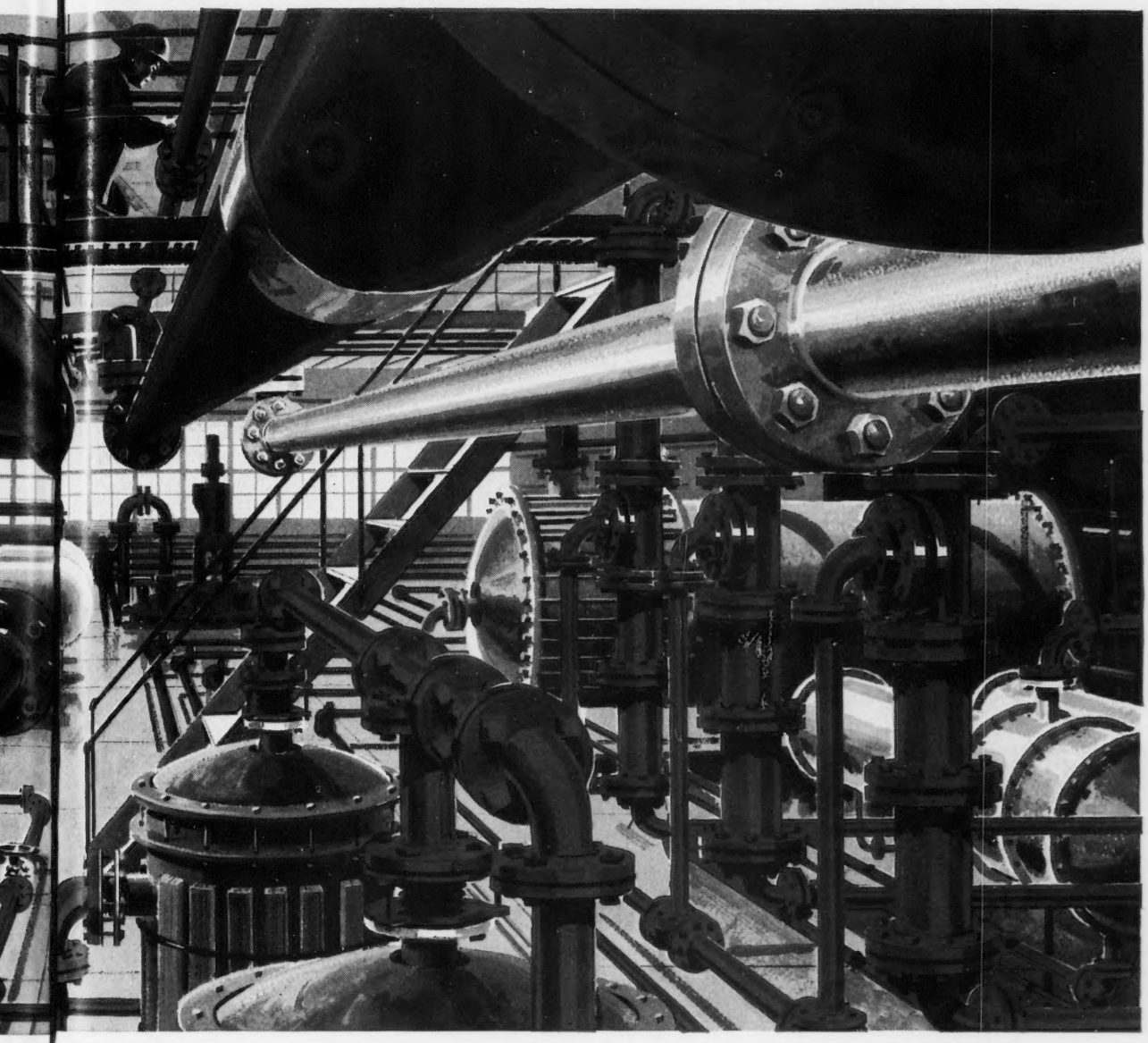

PRODUCT LOSSES

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High Temperature Coatings for Steel

(Continued From Page 16)

tion residue left on the surface from the priming operation will prevent adhesion of the topcoat.

Summary

1. Adequate surface preparation is a necessity to achieve reasonable coating life.
2. Sandblasting is the preferred method of surface preparation, with emphasis on the proper grit size of the abrasive.
3. Products considered for high temperature service should be field tested under actual operating conditions.
4. The service life of each high temperature coating tested was improved substantially by the application over a permanent primer such as the inorganic zinc silicate coating.

Acknowledgment

The author thanks Victor Garcia, chemist, for the assistance rendered and expresses appreciation to numerous friends who gave encouragement and helpful comments. He also thanks The Firestone Tire & Rubber Company for permission to publish this article.

References

1. Frank N. Speller. Corrosion—Causes and Prevention. McGraw-Hill Book Company, Inc., New York, N. Y., 1935.

DISCUSSIONS

Question by Alfred E. Hiller, Freeport Sulphur Co., Port Sulphur, Louisiana:
What coating system do you use where it is impossible to use sandblasting? Have you used a phosphate treatment prior to using a silicone coating over a non-sandblasted surface?

Reply by Gatewood Norman:

I assume that the inquiry is only about those surfaces which operate at elevated temperatures, our standard procedure consists of sheathing the material of construction with light gauge aluminum. We regard this from an engineering point of view as a very inferior solution to the problem. While it does give us the desired cosmetic effect, it does not prevent damage to the substrate due to moisture penetration during those periods when the units are shut down. We would much prefer to sandblast the areas if possible and protect them with the system covered in our test work which consisted of a permanent prime of an inorganic zinc silicate topcoated with a high temperature silicone paint.

Answer to the second question (use of silicone coating over non-sandblasted surfaces) is affirmative. We have found that it does to some extent increase the life of the organic finish. However, the percentage of improvement seems less than 15 percent.

Question by T. R. Hopper, Socony Products Company, Metuchen, New Jersey:
What did you mean when you said that above 300 F you had trouble getting adhesion to the inorganic silicates? I saw slides showing excellent adhesion of silicones to the inorganic zinc silicate primer at temperatures above 600 F.

Reply by Gatewood Norman:

Adhesion of the silicones to the inorganic zinc silicate is excellent even at temperatures to 1200 F continuous. However, this is true only if the top coat is applied before the coated equipment is put into service. If it is not possible to apply the top coats immediately and the equipment is heated to temperatures above 300 F, the silicate undergoes a change of some type, and subsequent attempts to apply silicone top coats always result in failure by loss of adhesion.

Question by Stanley L. Lopata, Carboline Company, St. Louis, Missouri:
My question has to do with why silicone coatings did not stick to inorganic zinc silicate coatings if the zinc silicate coating had been heated above 400 F prior to topcoating. Zinc silicate coatings are based on sodium silicate, commonly known as water glass. At temperatures above 300 F, the water glass fuses into an insoluble glass with a relatively slick surface. Coatings do not bond to glass as a rule.

There is another type of inorganic zinc coating on the market which is not based on sodium silicate where the vehicle is stable to 1700 F. Therefore, I believe that this inorganic zinc coating, which is based on a silicone oxide polymer, can be heated to temperatures to the vaporization point of the zinc, which is 750 F, cooled down and this coating can be topcoated with a silicone coating without resultant loss of adhesion or bonding problems.

Reply by Gatewood Norman:

You are correct in that there is another type of inorganic zinc coating which is not based on sodium silicate which might permit successful topcoating if the inorganic had first been heated to temperatures up to the vaporization point of zinc (750 F). This point merits investigation. It has been found, however, that overcoating can be a problem with inorganics using vehicles other than sodium silicate. A good deal of investigation work has been done with the inorganic zinc phosphates at high temperatures, and it has been found that these sometimes present unusual overcoating problems once the inorganic has been heated before overcoating.

It is my personal feeling that we are working in an area here where very little is known and that large scale applications should not be made on the basis of theoretical considerations but rather on very extensive field testing.

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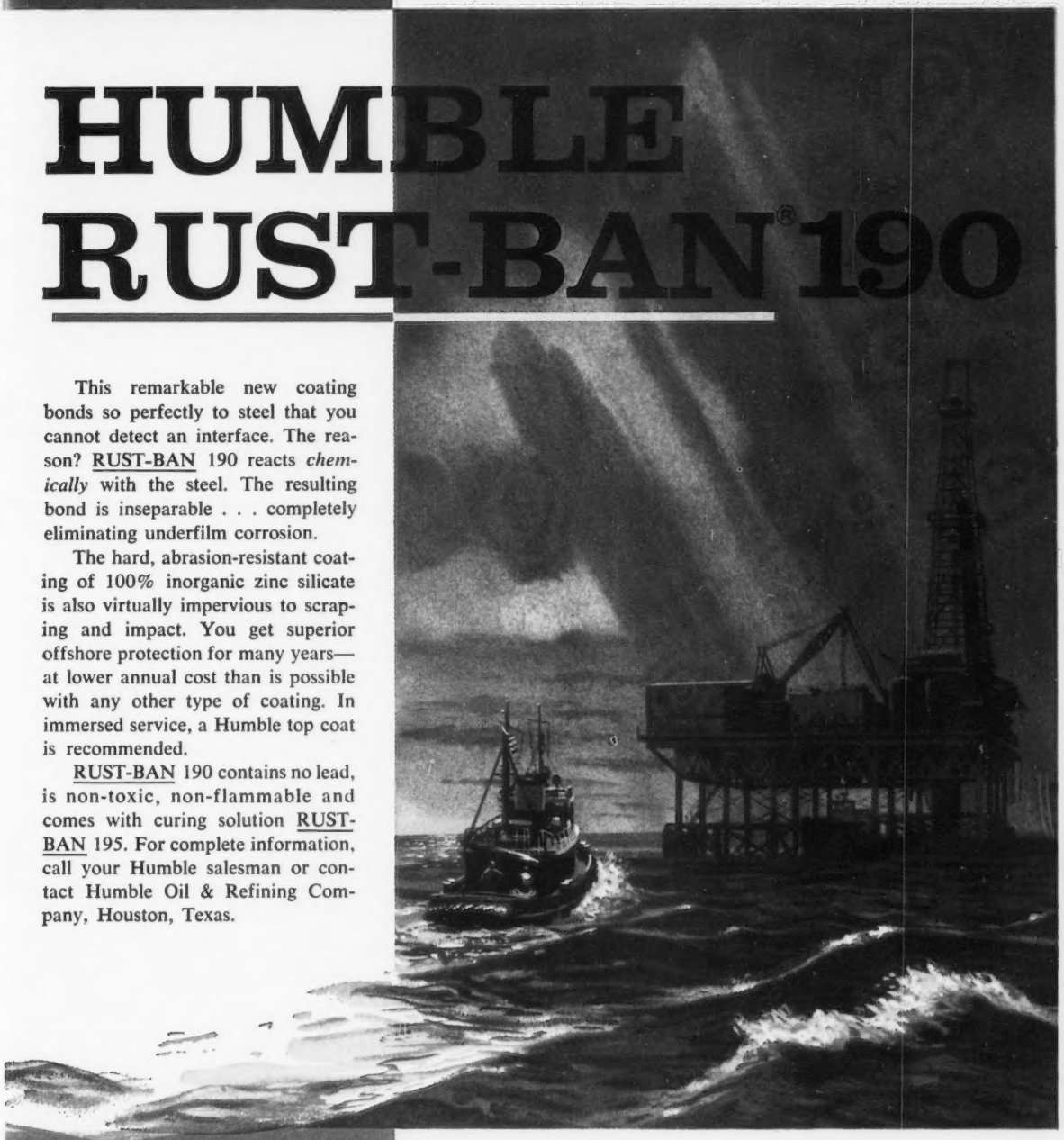

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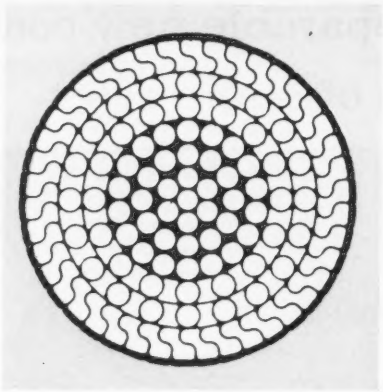

Figure 1—Locked coil wire rope (cross section).

Laboratory Development of Corrosion Inhibiting Coatings for Mine Hoist Wire Rope*

W. Dingley
Department of Mines and Technical Surveys
Ottawa, Ontario
Canada

Abstract

Results of laboratory tests are given on a compound designed to protect galvanized steel wire mine hoist rope. In a preliminary screening test it was learned that a combination of a road-construction asphalt, zinc chromate and trichlorethylene gave better results than a number of compounds presently used for wire rope protection.

A second series of tests on zinc coated wire from mine hoist rope, using various proportions of asphalt, zinc chromate and trichlorethylene, showed that coatings having an asphalt to zinc chromate ratio of about 1:1 gave best results. The asphalt-zinc chromate-trichlorethylene coating is recommended for both used and unused ropes. 5.3.4, 8.10.3

Introduction

IN THE MINES throughout the world there has been a great loss of time, material and human life due to metal corrosion. Some idea of the importance of this problem may be obtained from the 75 different references to corrosion which appeared in the proceedings of the Institute of Mining and Metallurgy conference on "Wire Ropes in Mines" which was held in 1950.[1] These references indicate that most of this corrosion has taken place in the hoisting ropes, due largely to the penetration of moisture between the individual wires.

Asphalt, bitumen, lanolin, oils, greases and combinations of these compounds have been applied to ropes during manufacture and during service to protect them from this moisture. Zinc and lead powders and colloidal graphite, suspended in lubricants, also have been used.[2] Chemical compounds with water displacing properties have appeared more recently.[3] It now is well established that in most mines ropes consisting of zinc-coated steel wires give appreciably longer service than do those consisting of bare wires.[4] Zinc-coated wires are being used extensively in ropes which previously had been very difficult to protect owing to their closely woven nature, such as the one shown in Figure 1.

The work reported here was done in response to a request from a Canadian company for assistance in solving a difficult corrosion problem encountered in connection with their zinc-coated hoist ropes. In spite of frequent applications of various types of compounds, corrosion had reduced the useful life of these ropes to 18 months.

Examination of an unused rope revealed a small amount of zinc and iron corrosion at numerous locations on individual wires that had been removed from the first, second and third rows. Examination of a used rope showed that quite severe corrosion had taken place on the outer surfaces of all the wires in the first row and also that the zinc coatings on all of the wires in all of the rows had been almost completely consumed by corrosion. The rope compound found on the unused rope was not visible in the corrosion products from the used one. Compounds applied while the ropes were in service apparently had not penetrated further than the outer row of wires. Chloride was the predominant anion in the corrosion products.

In view of these findings a program was initiated to attempt to produce a compound that could be used on wire ropes to increase their resistance to corrosion under the conditions in this particular mine. The purpose of this article is to outline the work leading to development of such a compound. The resulting coating material has shown exceptionally good results in laboratory

* A paper presented at a meeting of Eastern Division, Canadian Region, National Association of Corrosion Engineers, Montreal, Quebec, November 14-16, 1960.

TABLE 1—Corrosion Resistance Imparted to Zinc-coated Steel by Chromate Compounds in Asphalt Coatings
(Hours to first rusting in an intermittent immersion test using 5 percent sodium chloride)

Ratio (Asphalt/Compound)	Zinc Chromate Pigment A	Zinc Chromate Pigment B	Barium Potassium Chromate Pigment	Sodium Chromate (Anhydrous) C.P.
5:1	96	72	60	60
2:1	500	200	.	...
5:4	500	200	85	180
5:2	420	235	..	...

Asphalt coating with no chromate—48 hours.
Best rope compound used at mine—4 hours.

corrosion tests, and arrangements are being made now to test it under actual conditions in the mine.

Experimental Procedure

Specimen Preparation and Corrosion Test Method

Protective coatings investigated during this work all were tested by the same standard procedure so they could be arranged readily in order of merit. Each test specimen was prepared as follows:

1. A 6-inch length of zinc coated wire, obtained from the first (outside) row of an unused rope (see Figure 1), was thoroughly brushed in suitably stabilized liquid trichlorethylene and then degreased in the vapor of the same material. It then was placed in a desiccator.

2. It was removed from the desiccator and hand-dipped in the coating material being tested.

3. It was hung vertically for 24 hours at room temperature (70 F) to allow volatile constituents of the coating material to evaporate.

Each test specimen so prepared was subjected to an intermittent immersion test in 5 percent sodium chloride solution to determine its resistance to corrosion. Although these conditions obviously did not exactly duplicate conditions in the mines, they did include the frequent wetting and partial drying which usually take place in such an environment. It will be recalled, also, that chloride was the predominant anion in the water from the mine in question. Having found the coating with the best corrosion resistance in the laboratory test, it was planned to test it further in the mine to ensure that the results obtained in the laboratory were not misleading.

In this corrosion test each coated specimen was suspended vertically from the arms of a dipping machine with vinylidine chloride cord. By this means it was dipped into and withdrawn from a 2000 ml glass beaker containing 1900 ml of 5 percent sodium chloride solution, each complete cycle requiring one minute. The specimen was examined on each working day and a note was made of the time to first appearance of red iron rust and to general rusting. (General rusting was indicated by the appearance of rust spots on various parts of the surface of the specimen, and by a sudden increase in the amount of iron rust in the solution.)

Development of the New Coating Compound

During the first part of the investigation a considerable number of coating materials were compared in the laboratory test described above. These included three types of rope compound presently used and a wide variety of organic and inorganic materials known to protect metals against corrosion under certain circumstances. The best of the commercial rope compounds gave effective protection for only four hours in the laboratory corrosion test. Of the other materials investigated, a road-con-

(Continued on Page 26)

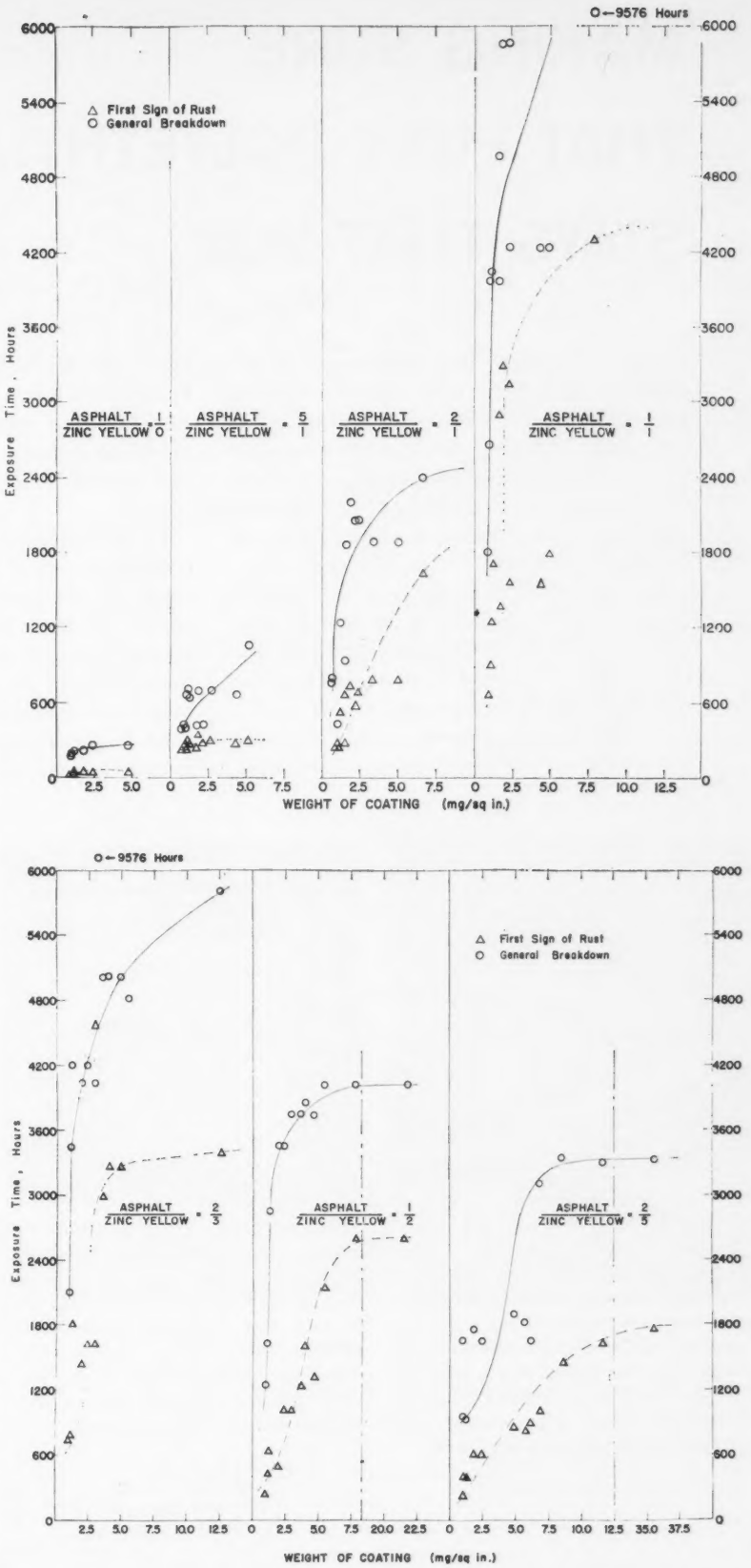
O←9576 Hours
△ First Sign of Rust
○ General Breakdown
Exposure Time, Hours
ASPHALT / ZINC YELLOW = 1/0
ASPHALT / ZINC YELLOW = 5/1
ASPHALT / ZINC YELLOW = 2/1
ASPHALT / ZINC YELLOW = 1/1
WEIGHT OF COATING (mg/sq in.)
ASPHALT / ZINC YELLOW = 2/3
ASPHALT / ZINC YELLOW = 1/2
ASPHALT / ZINC YELLOW = 2/5

Figure 2—Corrosion resistance of asphalt containing increasing proportions of zinc yellow chromate pigment, applied on zinc coated steel wire. Top and bottom charts show intermittent immersion test using 5 percent sodium chloride solution.

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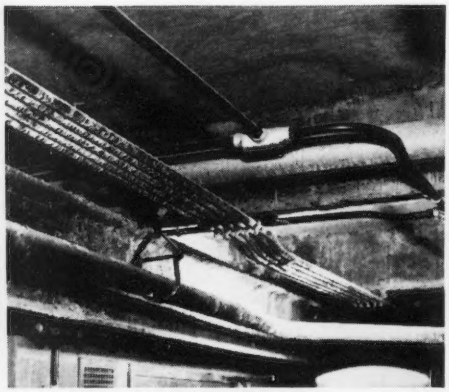

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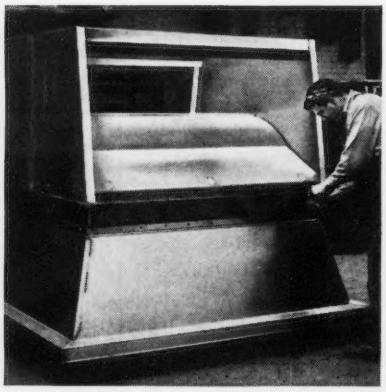

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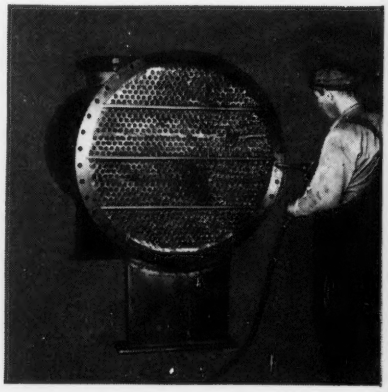

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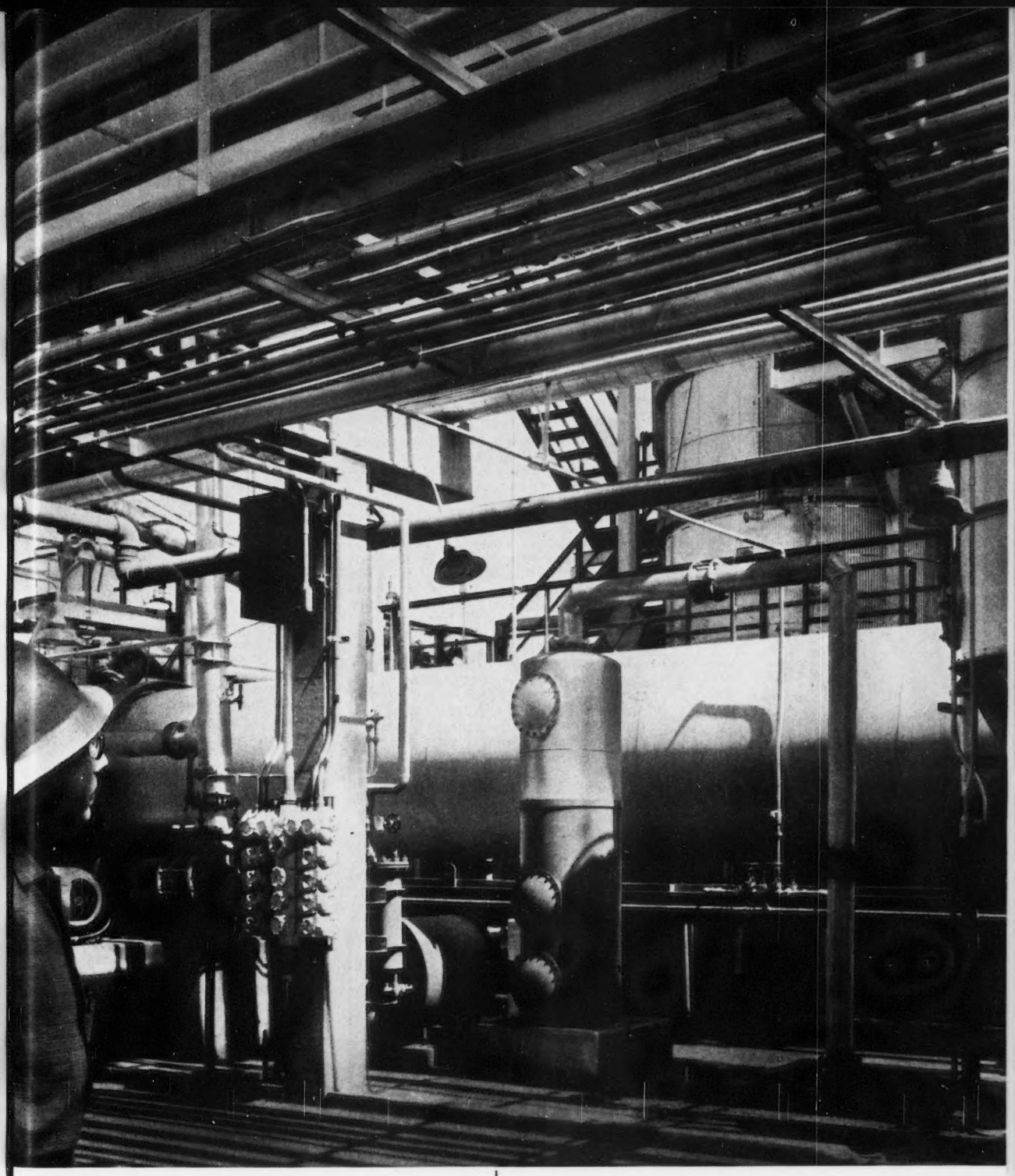

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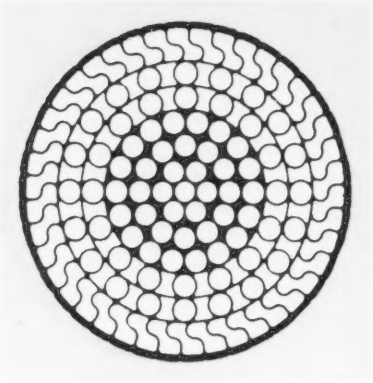

Coatings for Wire Rope

(Continued From Page 23)

struction asphalt gave particularly good results as a base. It also was found that:

1. Chromates were the most effective of the additives tested, when an asphalt-base coating was used;

2. Trichlorethylene was an excellent thinner for the asphalt-chromate coatings due, at least partly, to its good wetting properties and high volatility.

For these reasons it was decided to pay particular attention to combinations of asphalt, chromate and trichlorethylene during the latter part of the investigation.

Chromate Inhibitor Action Compared

The next step was to compare the inhibitor action of various chromates when used in combination with the asphalt and the trichlorethylene. As shown in Table 1, the two zinc chromate (zinc yellow) pigments tested proved to be much superior to a barium potassium chromate pigment and to chemically pure anhydrous sodium chromate. It also was observed that one of the zinc chromate (zinc yellow) pigments gave considerably better results than the other. Finally, the ratio of asphalt to chromate pigment appeared to be very important.

In the next phase of the investigation experiments were performed to determine the preferred proportions of asphalt, the better zinc chromate pigment, and trichlorethylene in the coating mixture. Whereas mixing of the constituents in earlier experiments had been done comparatively inefficiently by hand, in these later experiments it was done much more effectively by an electric mixer (30 minutes at approximately 8000 revolutions per minute).

Mixtures of the asphalt and zinc yellow were made up in the following ratios: 5:1, 2.1, 1:1, 2:3, 1:2 and 2:5. Each mixture was divided into 12 equal portions, and a different amount of trichlorethylene was added to each. Each of the resulting 72 mixtures was applied by dipping to a different set of three steel panels, each one inch square. After drying, the average weight of each of the 72 types of coating per unit of area was determined.

Coatings were applied in the same way to 72 sets of two zinc-coated steel wire samples taken from an unused mine hoist rope. After drying, the resulting specimens were subjected to the corrosion test already described. In Figure 2 the number of hours to first rusting and the number of hours to general rusting are plotted against the average coating weight in the case of each of the 72 types of coating. In Figures 3 and 4 the compositions of these different types are plotted on ternary diagrams, which also show the weights of the coatings. The coatings having the best resistance to corrosion are indicated. The latter are listed in Table 2.

TABLE 2—Compositions of Coatings Most Resistant to Corrosion

Coating Composition (Per Cent By Weight)			Ratio
Asphalt	Zinc Yellow	Trichlorethylene	Asphalt/Zinc Yellow
25.0	25.0	50.0	1:1
22.7	22.7	54.6	1:1
22.7	34.1	43.2	2:3
22.2	33.3	44.5	2:3
20.0	30.0	50.0	2:3
18.1	27.3	54.6	2:3

Discussion

It should be emphasized that although early experiments were not as carefully controlled as the ones summarized in Figures 2 to 4 they provided an adequate over-all picture. In addition to showing that one zinc chromate pigment was superior to other chromates investigated as a corrosion inhibitor, results presented in Table 1 showed that the degree of inhibition afforded zinc-coated steel was greatest when the asphalt/zinc yellow ratio was about 1:1. Results obtained were inferior when this ratio was substantially increased or decreased. This was substantiated by the experiments summarized in Figure 2.

Data summarized in Figure 2 show that a coating with an asphalt/zinc yellow ratio of 1:1 possesses the best corrosion resistance per unit of weight. However a coating with a ratio of 2:3 also resists corrosion exceptionally well. One coating with a ratio of 1:1 and another with a ratio of 2:3 had not reached general rusting at the end of 9576 hours.

Six of the eight coatings which resisted first rusting for more than 3000 hours had the three ingredients in fairly similar proportions (see Figure 3), and the same six coatings resisted general rusting for more than 5000 hours (see Figure 4). It is reasonable to assume therefore that any compound with a composition like that of any of these six would give excellent corrosion protection to galvanized mine hoist ropes. It should be pointed out that two highly resistant coatings located outside this preferred area were much thicker.

It may be added that the brushing, dipping and spraying characteristics of

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the best six coating compounds were very good. The coatings dried to touch quite rapidly and had excellent adherence when subjected to bend tests. They penetrated well into narrow recesses and joints, at least partly because of the excellent wetting properties of the trichlorethylene. It was found that this new compound could be applied over other types of rope compounds and still give considerable protection to the rope. It also could be applied satisfactorily to the surfaces of lightly rusted and of wet wires, and would impart somewhat improved corrosion resistance to wires in these conditions.

Because the zinc yellow pigment in the coating has a low solubility, it leaches out very slowly, so its inhibitor action continues over a long period.

Zinc coating applied to this particular type of mine hoist rope is designed to prevent the steel from corroding. That it does so is shown by inspection of used zinc-coated ropes from which it is almost entirely removed in the process of protecting the steel.

The purposes of the new coating described in this article are twofold:

1. If the coating is applied at the time the rope is manufactured, it will reduce the rate at which zinc corrodes, thus enabling it to give longer protection to the steel.

2. If the coating is applied to rope already in service, it will tend to protect any remaining zinc and any steel surfaces that have become exposed from further corrosion. The small amount of moisture passing through the coating will be inhibited by the slowly-dissolving chromate.

Conclusions

Data presented in this article, based on laboratory experiments, indicate that a compound containing asphalt, zinc chromate pigment and trichlorethylene in the proper proportions will increase substantially the corrosion resistance of closely woven zinc coated mine hoist wire ropes; also that the compound has considerably greater protective value than the commercial rope compounds also tested during this investigation.

The new compound can be applied by conventional methods, has good wetting properties and adherence, dries rapidly, and can be applied over other rope compounds.

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1. Proceedings of the Conference on Wire Ropes in Mines, Sept. 1950. Published by the Institute of Mining and Metallurgy, 1951.
2. C. H. Layton, *Iron and Steel Engineering*, **29**, 172 (1952) July-Dec., (discussion).
3. Proceedings of the Conference on Wire Ropes in Mines, Page 129, Sept. 1950. Published by the Institute of Mining and Metallurgy, 1951.
4. *Ibid*, Page 793.

(EDITOR'S NOTE: See also: Corrosion and Protection of Mine Hoist Ropes, by F. L. LaQue, CORROSION, **6**, No. 1, 8-13 (1950) Jan.)

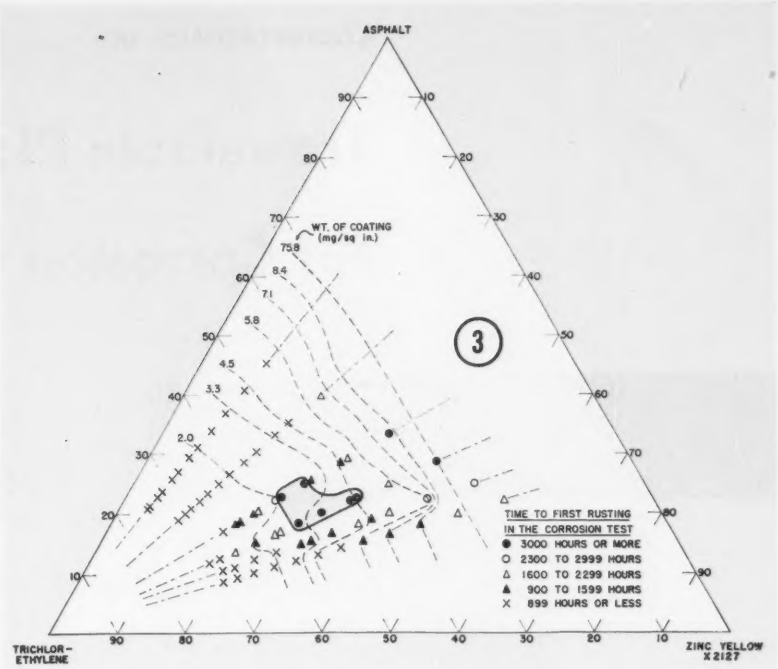


Figure 3—Corrosion resistance of coatings produced with various mixtures of asphalt, zinc yellow chromate pigment and trichlorethylene, on zinc coated steel wire. An intermittent immersion test using 5 percent sodium chloride solution. Legend shows hours to first rusting.

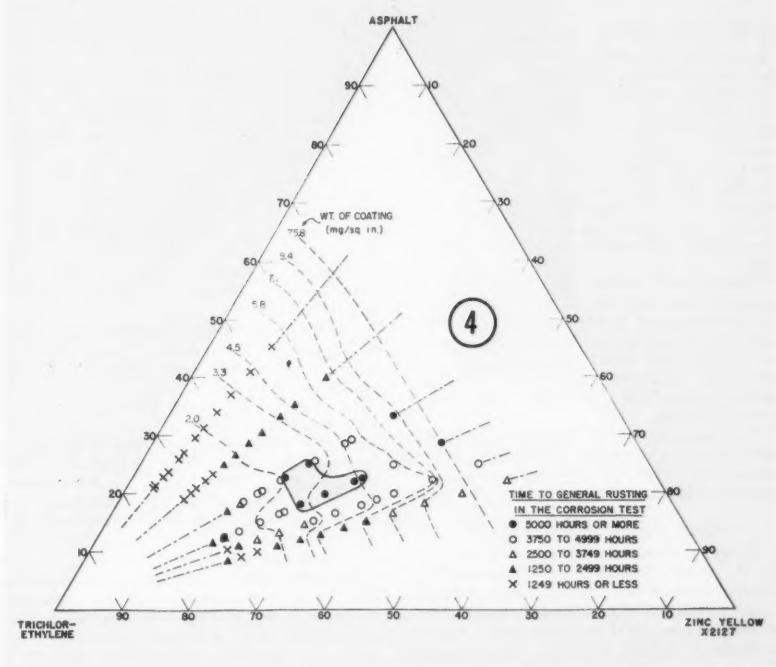


Figure 4—Corrosion resistance of coatings produced with various mixtures of asphalt, zinc yellow chromate pigment and trichlorethylene applied on zinc coated steel wire. Intermittent immersion test using 5 percent sodium chloride solution. Legend gives hours to general rusting.

. . . for something new in corrosion literature, see Pages 36, 58 and 74 in this issue.

Characteristics of

Trowelable Plastic Coatings For Corrosion Control*

Abstract

Constituents of, recommended formulations, application methods and indicated uses of the principal multiple-component, filled trowelable plastic coatings are discussed. Special attention is given to epoxy formulations, which the author believes to be the best currently available. 5.4.5.

J. H. Cogshall and Allen M. Smith III

Pensalt Chemicals Corp.

Natrona, Pa.

TROWELABLE coatings of substantial thickness for corrosion protection should be distinguished from thin film paints, metallic, or ceramic deposits for corrosion protection. Towelable coatings are defined herein as coatings of mortar consistency, at least 1/16 inch in thickness, usually applied by a trowl but capable of being applied by spray techniques. This discussion is additionally limited to those coatings which are chemically setting at ambient temperature.

These limits relate to coatings whose primary use and development has been for protection of concrete, although some also are showing promise as protectives for metals and other surfaces. Also, because of thickness, they have long life when exposed to corrosive and erosive environments.

The importance of protecting concrete surfaces is shown in a recent survey[1] where it is called the number one maintenance problem in plants today.

New Plastics Breakthrough

Modern trowelable coatings date from 1871[2] when asphaltic or bitumen-type coatings came into general use. Bituminous coatings, though still used, have moderate chemical resistance and cannot withstand many forms of industrial abuse. Phenolic trowelable coatings were introduced about 25 years ago followed after a few years in fairly quick order by polyesters, latexes, furans and finally, by the latest and most promising trowelable coating systems, the epoxies and polyurethanes.

Research necessary to produce a trowelable coatings is both extensive and protracted and this is especially true of the modern resin mortars. The work involves the screening of several thousand potential products and results in an evaluation process that usually lasts six or seven years.

Trowelable coatings for corrosion protection fall into five classifications:

Bituminous Trowelable Coatings are asphalt, bitumen, or coal tar based products filled with chemical resistant aggregate. These may be either hot or cold applied. While such coatings are not truly chemically setting, they do occupy a significant place historically in the development of trowelable coatings. Bituminous coatings generally are one-component systems with the filler added in the field.

Latex Trowelable Coatings are combinations of rubber-like, liquid binders and cement-aggregate fillers.[4] Latex coatings are two-component systems that are composed of Portland cement or other cementitious materials with selected sands and aggregates and a latex binder. Water in the latex mixture serves as a setting agent for the cementitous product while the polymers act as a matrix imparting improved chemical resistance, bonding characteristics and wear resistance.

Polyester Trowelable Coatings usually are based on resin made by reacting propylene glycol with a mixture of maleic anhydride and phthalic anhydride to give a resinous polymeric material.[3] Reactive diluents are sometimes used. Polyester coatings generally can be classified as three-component systems consisting of a resin, a catalyst and an inert filler. The catalyst is sometimes a part of the inert filler.

Epoxy Trowelable Coatings are built around resins made by reacting epichlorhydrin with bisphenol A. This resin in turn is catalyzed with such reagents as polyamines, polyamides or other hydroxyl-bearing catalysts. They generally can be classified as three-component systems consisting of a resin, a catalyst and an inert filler.[6]

Furthermore, the epoxy resin may be modified with solvent diluents, cross-linking diluents, coal tars, furans, phenolics, polysulfides, or a host of others. Of several thousand possible formulations of epoxy trowelable coatings several hundred are being marketed today.

Miscellaneous Systems

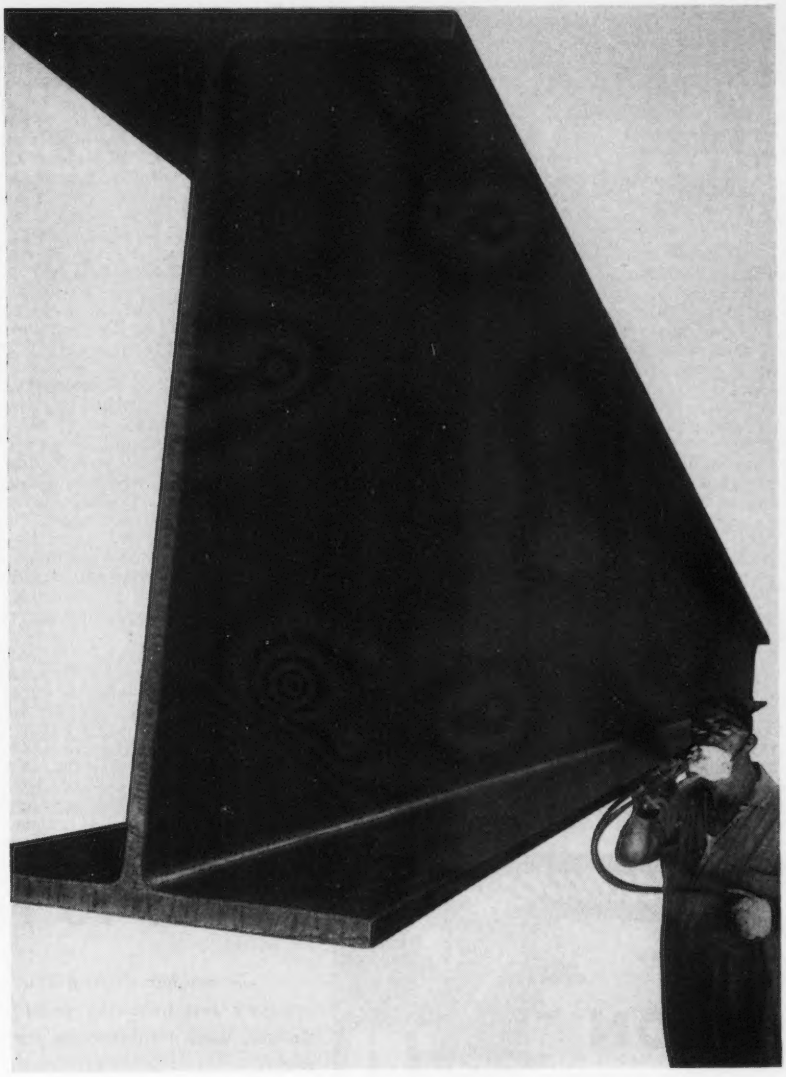
Some trowelable coatings find little use due to defects. These include furans and phenolics which fail because of brittleness, lack of permanent bond and shrinkage. Polyurethane coating systems are interesting but have not shown sufficient improvement over epoxies for immediate consideration.

The success of any coating is dependent on its being applied over clean, sound, usually dry concrete surfaces. It is true that latex mortars must have a wetted surface to be coated successfully and that some polyester and epoxy mortar manufacturers claim they can be applied over damp surfaces. In the first case the moisture is controlled. In the second case the surface must be barely damp and completely neutral. Even so, to formulate for this result much of the chemical resistance and some of the physical strength must be sacrificed.

Asphaltic trowelable coatings, one of the first to be used, still are in use today. A coating system will be discussed here, one giving maximum corrosion protection while not sacrificing too many desirable physical properties. This asphaltic trowelable coating system is applied in somewhat the same manner as a built-up roof. First is a prime coat of emulsified asphalt reinforced with roofing felt or glass cloth. This is topped by a layer of asphalt mied with silica sand and aggregate. Thickness of the coating should be at least one inch and usually is 1¼ inch to 1½ inch. One of the best materials is native

(Continued on Page 30)

★ A paper presented under the title "Trowelable Coatings for Corrosion Protection," at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.



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Trowelable Plastic Coatings

(Continued From Page 28)

Trinidad Lake asphalt because of its lesser tendency to oxidize and embrittle.

The asphalt trowelable coatings described here have good acid resistance with an installed cost in a range comparable to resinous coatings. Many engineers think asphaltic coatings have poor chemical resistance and are relatively inexpensive.

These coatings have good moisture and acid resistance. They generally are not affected by salts but are attacked by oxidizing acids, gases and have little or no resistance to organic compounds and solvents.[7] They perform best in strong sulfuric acid and poorest in organic solvent service.

They have good flexural strength, poor compressive and tensile strength and low bond strength. For these reasons they must be reinforced and must be thick. Impact and abrasion resistance are good but resistance to static loading is very poor and bond is minimal. These last two defects are the chief reasons why asphaltic trowelable coatings are being replaced rapidly by other more durable systems.

Lack of resistance to static loading limits the ability of such flooring to handle point loading due to heavy equipment or heavy wheeled vehicles. Asphaltic coatings modified with epoxy have improved static loading but have not proved as durable. Modification with furans, phenolics or neoprenes has not been notably successful.

As asphaltic coatings age they tend to oxidize and embrittle. This, coupled with their poor bond, results in failure starting generally about the fifth year. Cracks develop, followed by fairly rapid undercutting and delamination.

Latex Trowelable Coatings

Latex trowelable coatings can be classified as cementitious products or as additives to concrete, but because the latex forms a matrix within the cementitious mass they may be considered chemical resistant coatings and will be so treated here. Latex formulations providing some degree of chemical resistance combined with good wear resistance and other physical characteristics are formulations containing styrene-butadiene or vinylidene chloride copolymers.

They are most often used as inexpensive repair materials whose corrosive conditions are mild, where traffic is moderate to heavy, and where speed and ease of repair is important. They impart improved performance to concrete with respect to chemical and physical characteristics. When exposed to sodium chloride, weather and heavy traffic they are a marked improvement over concrete and sometimes are used to restore and protect old wood floors or steel decking. Because of good water resistance they are widely used as a water proofing and decorative coating for masonry.

They generally are applied to a minimum thickness of ½ inch although they can be successfully feather edged. Recommended application procedures are: To a clean, sound concrete surface, saturate concrete with water by soaking. Remove excess water. Then brush a slurry of latex troweling mixture over the surface. Follow with the troweled-on coating consisting of a mixture of Portland cement, latex binder, silica fines and aggregate. Latex mortars have a pot life of 30 to 45 minutes and cure in 12 to 24 hours to a strength considerably above that of standard concrete.

Polyester Coating Systems

Polyester trowelable coatings once appeared to be the universal all-purpose trowelable coating. At present they are largely overshadowed by epoxy trowelable coatings. Generally, polyster trowelable coatings are slightly less chemical resistant than the epoxy trowelable coatings, particularly to strong alkalies, but they are more resistant than epoxies to oxidizing agents and free chlorine. Usually polyester mortars are less expensive than epoxy mortars, are easier to trowel, cure at lower temperatures and can, if the necessity arises, be applied to a damp surface.

These advantages appear to give them a lead over the epoxies. However, they have fairly high shrinkage rates and are defective in aging and weathering characteristics. While shrinkage may be reduced somewhat by using co-polymerized resins, it remains troublesome. Poor

(Continued on Page 32)

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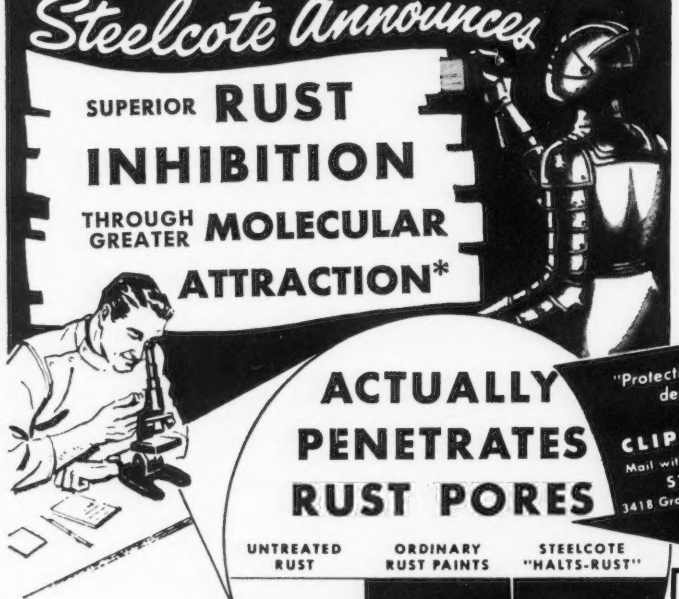

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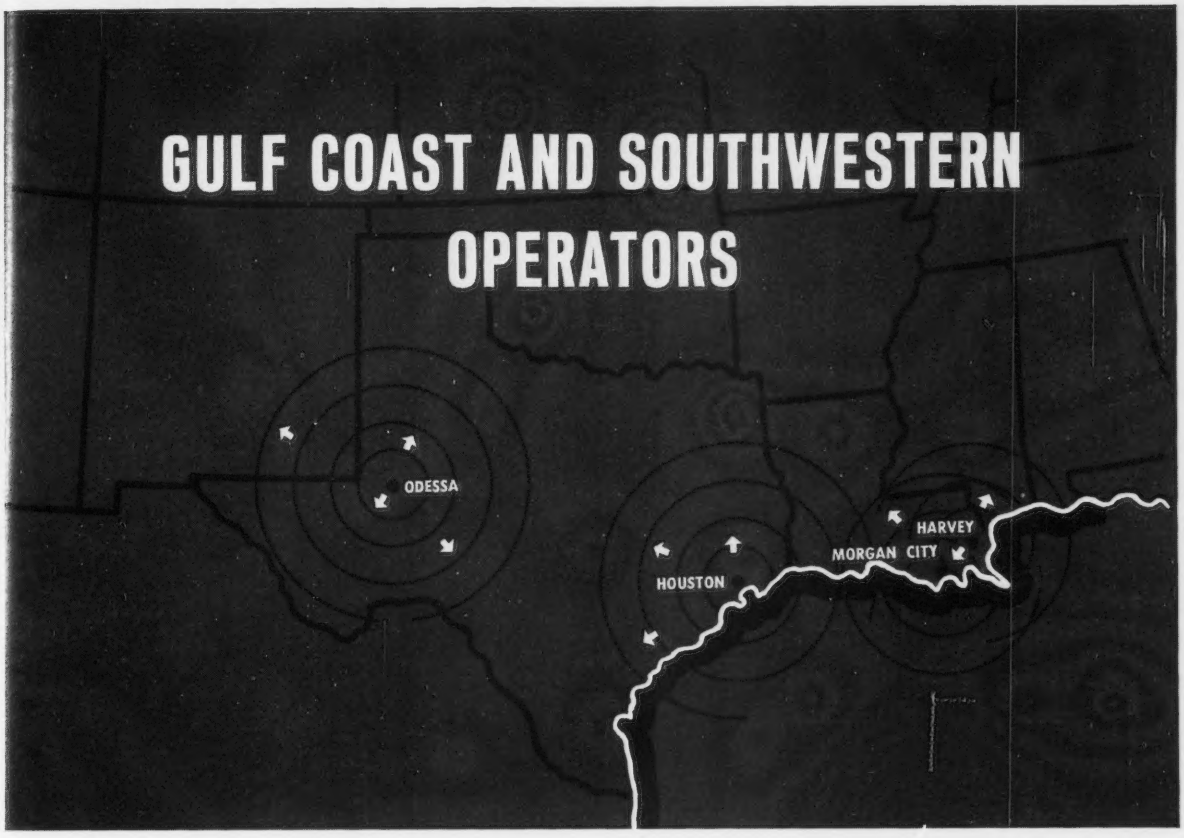

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BETTER COATINGS THROUGH RESEARCH

PLASTIC APPLICATORS, INC.

Trowelable Plastic Coatings

(Continued From Page 30)

weathering can be observed readily in objects made of glass cloth reinforced with some types of polyester resin. Improved results may be obtained by cross-linking with monomers, such as styrene, in the presence of catalysts and promoters. This and careful blending of the filler materials control expansion to about 19 x 10^{-6} and help to reduce shrinkage and prevent cracking and delaminating due to defferential expansion.

Polyester trowelable coatings, usually three component systems, are prepared by thoroughly mixing the resin with the reactive diluent and then adding a blend of inert fillers to form a stiff mortar. A variety of colors and finishes are available and appearance is like well-finished dense concrete. Addition of colors or some types of reactive diluents or modifiers tend to lower the chemical resistance. Polyesters trowel well and can be applied at temperatures as low as 50 F. Some polyester trowelable coatings can be applied to damp surfaces. Pot life is two to three hours and it fully cures in 24 to 36 hours, at 75 F.

Epoxy Coating Systems

Epoxy coating systems have very good chemical resistance to most organic and inorganic acids except strong oxidizing acids, excellent chemical resistance to alkalies, salts, caustics and to most organic chemicals and solvents. They have outstanding bond strength (stronger than the material bonded to, in some cases), high tensile and compressive strength and low shrinkage.

Most epoxy formulations have a high dielectric constant and good electrical resistance although carbon filled epoxies have been used as conductive protective coatings. Limited tests have shown them to have good radiation resistance. Some use has been made of trowelable epoxy coatings for coating concrete in areas exposed to radiation, such as reactor shields and waste disposal pools.

Epoxy systems having maximum corrosion resistance and good physical properties have three components consisting of an epoxy resin with a viscosity of 250 to 270 centipoises at 25 C. and a specific gravity of 1.11; a hardner essentially consisting of polyalkylene polyamine, such as diethylenetriamine; and an inert filler composed essentially of a mixture of ground quartz and silica, or in some instances, carbon.

The chief drawback of many formulations and of the system described above is that they produce a relatively brittle, inelastic material. So, unless shrinkage and coefficients of expansion are matched to those of concrete, differential expansion can cause cracking or delamination of the coating system. A second drawback is that the amine-type hardner can cause dermatitis or skin rash on some sensitive persons.

Flexibilizing Agents Help

The addition of flexibilizing agents is one means of overcoming the inelastic nature of epoxy coatings. Field results show that flexibilized formulations have advantages only in extreme thermal shock areas and may have considerably lowered chemical resistance and physical characteristics. Entirely new "epoxy alloys" are expected shortly having advantages of the "amine type" epoxies described above while exhibiting remarkable "toughness", flexural strength and a high modulus of elasticity.

Attempts to lower the toxicity of the epoxy systems and to insure easier field mixing call for a substitute for the polyamine-type hardner. To date, less toxic formulations have reduced chemical resistance and physical characteristics. Some progress can be expected in lowering toxicity and in having formulations that are easier to mix and handle in the field.

Epoxies are blended with many other resins, modifiers and solvents. Mixtures with coal tar derivatives have displayed somewhat lower chemical resistance with a tendency toward age-embrittlement.

Most failures of epoxy coating systems results from inadequate or improper formulation of ingredients, improperly prepared surfaces or improper handling.

Clean, Strong Surfaces Required

It cannot be too strongly emphasized that epoxy coatings must be applied to strong, sound, clean surfaces. Also, unless care is taken in field mixing by following the manufacturer's instructions, poor results can be expected. Although these requirements may be troublesome, the advantages to be gained through the use of these coating materials encourage the engineer to insure proper use and application.

Adequate formulation can be assured by requiring that the formulator report the ingredients in his formulation in general terms. Furthermore, the engineer should satisfy himself that the formulation will resist the chemical environment involved by testing in accordance with test procedure suitable for the service conditions, and that all physical data are reported and substantiated according to appropriate ASTM test methods.[8] In particular, the engineer will wish to be sure that the thermal expansion of the epoxy system closely matches that of the surface to be coated. Plant testing and investigation of similar uses will support data supplied by the formulator.

Proper application can be insured by insisting that all concrete surfaces be sound and clean. Surfaces should be dry except where special primers for damp surfaces are specified. All concrete should be well cured and have a compressive strength of at least 3,000 psi. Field tests of concrete strength can be made easily with portable instruments. Because of their broad chemical resistance, extreme toughness, ease of application and good bond strength, epoxy coatings will play an increasingly larger role in protection of concrete floor and other surfaces.

A reliable business forecast[1] shows

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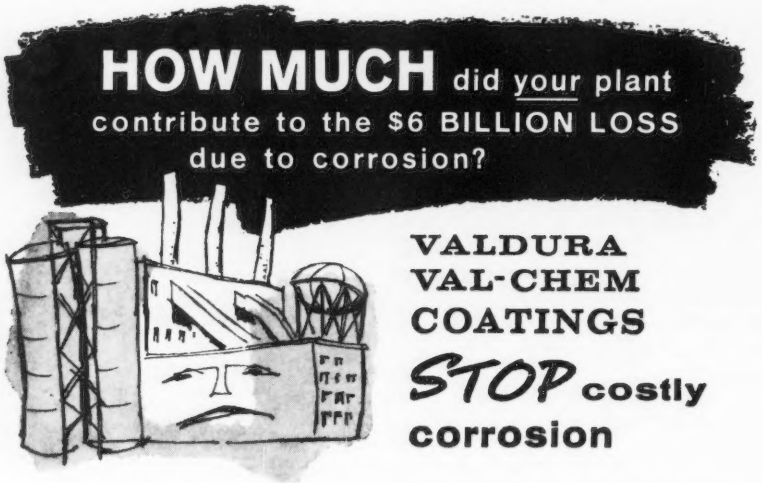

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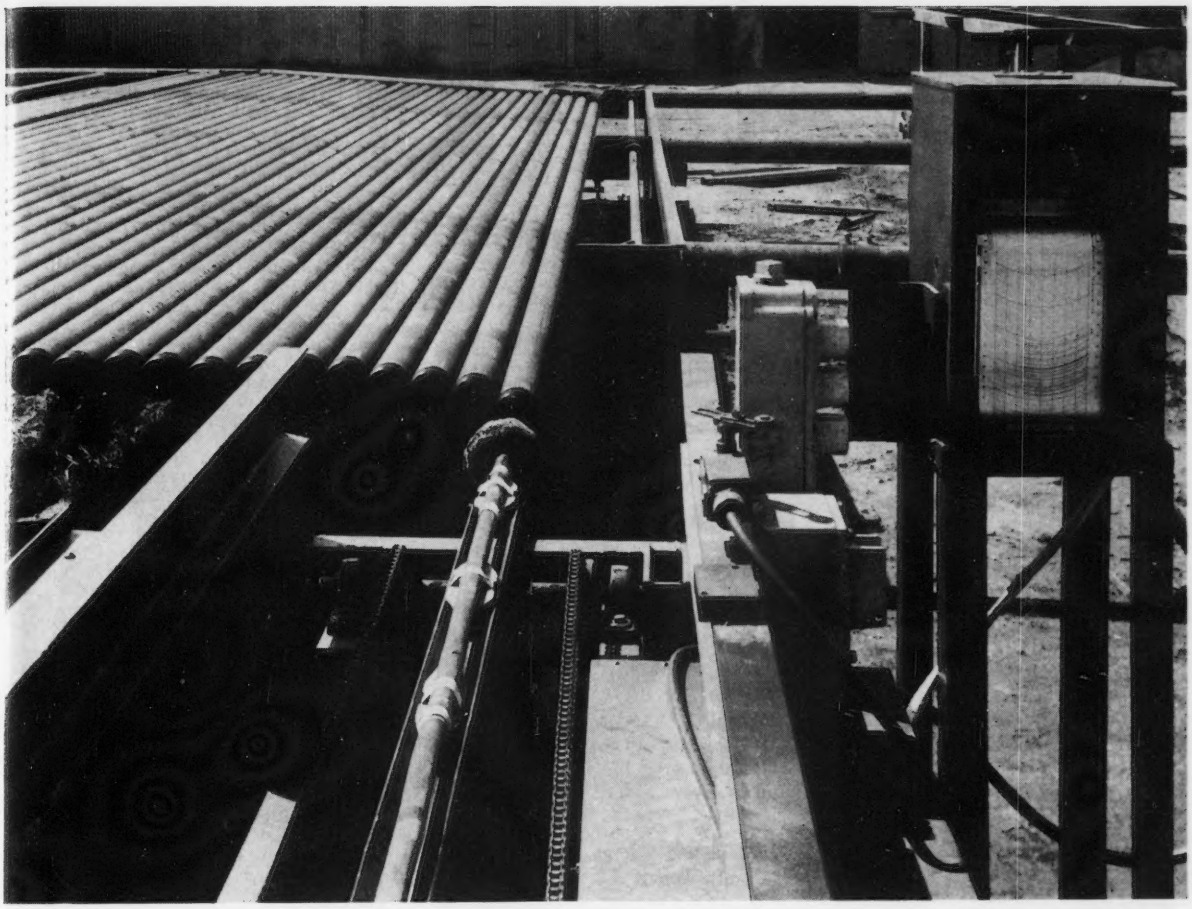

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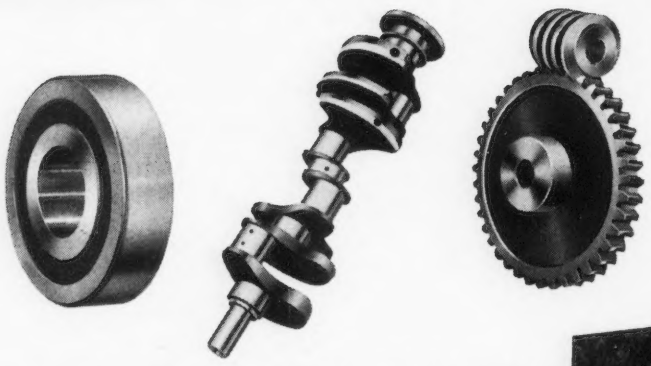

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Plastic Coatings –

(Continued From Page 32)

that the use of trowelable epoxy coatings will increase 25 times in the next four years. The bulk of this increase will be for floors and concrete surfaces. Many other uses are indicated also and new application methods have substantially lowered the cost of application.

Spray Equipment Now Available

Recently developed, inexpensive spray equipment now allows some trowelable epoxy coatings to be sprayed on surfaces at a rate four or five times that of hand troweling. The sprayed material is very dense and well bonded to the surface. Application of the heavily filled material on vertical surfaces is facilitated.

Application of trowelable epoxy coatings for wear protection and antiskid surfacing is rapidly growing. Wear resistance applications may account for a larger volume than chemical resistance. Ease of installation without plant shutdown, low cost repair of existing eroded floors, excellent long term wear resistance favor this trend.

Increasing use of trowelable epoxy coatings to line vessles, tanks and stacks for corrosion protection can be expected. Field trials have given promising results. Again, spray equipment promotes this use for protective linings.

Trowelable epoxy coatings also are being used as road repair materials for spalled areas and as non-skid coatings on bridges and at toll gates. Permanent center line markings for highways and permanent safety lane markings for plants have been installed using these types of formulation.

Inexpensive wall board, spray coated with an epoxy, makes a low cost, highly chemical resistant, easily cleaned exterior sheathing material for buildings. Paperboard sprayed with an epoxy coating and either trowel finished and painted or finish coated with plaster is more satisfactory and less expensive than some other building materials.

Other Applications Listed

Epoxies can be used advantageously and economically to coat and protect foamed glass and foamed silica, to coat insulation, machinery, pipe boots or shoes for protecting pipes at supports, to make emergency repairs of pipes and vessels, to protect or bond underground pipe, to rebuild and protect cooling tower fans and exhaust fans, to waterproof tops of brick parapets, to protect spandrel beams, to waterproof or protect roofing (particularly around vents), to bond acid brick and repair existing brick linings, to repair and build up broken curbs and platforms and to provide skid-resistant surfaces on steel grating, decking and other safety hazard areas.

References

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2. Repair and Protection of Problem Floors. *Maintenance* **39** 178 (1949) March.
3. Organic Protective Coatings. W. Von Fischer and E. G. Bobalek. Reinhold Publishing Corp.
4. Latex, Natural and Synthetic. Philip G. Cook. Reinhold Publishing Co.
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6. Epoxy Resins. H. Lee and K. Neville. McGraw-Hill Book, Inc.
7. Organic Chemistry, 3rd Edition. C. Fieser and M. Fieser. Reinhold Publishing Co.
8. Tentative Method for Testing the Chemical Resistance of Chemical Resistant Materials. ASTM-C-267-59T American Society for Testing Material.

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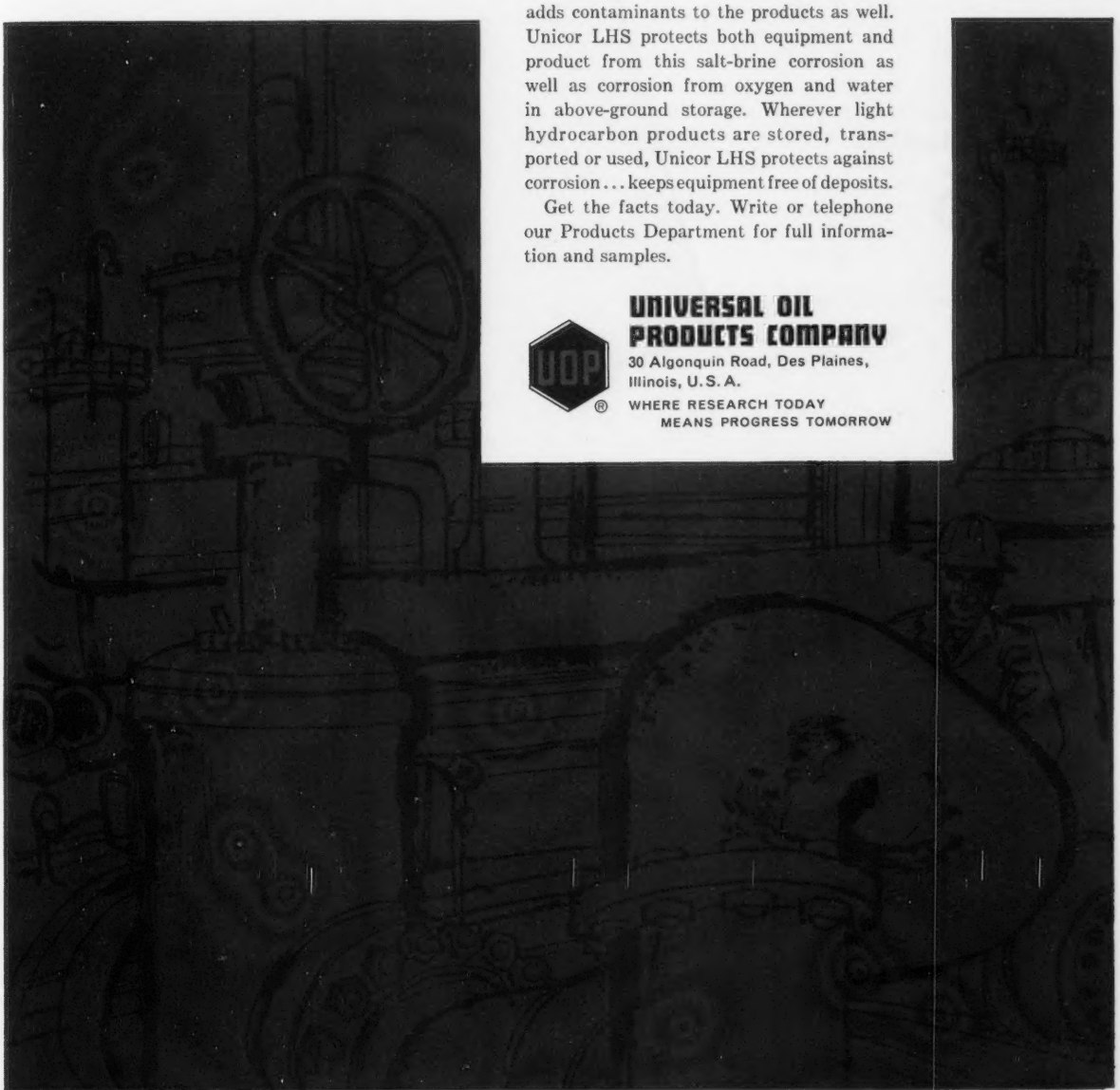

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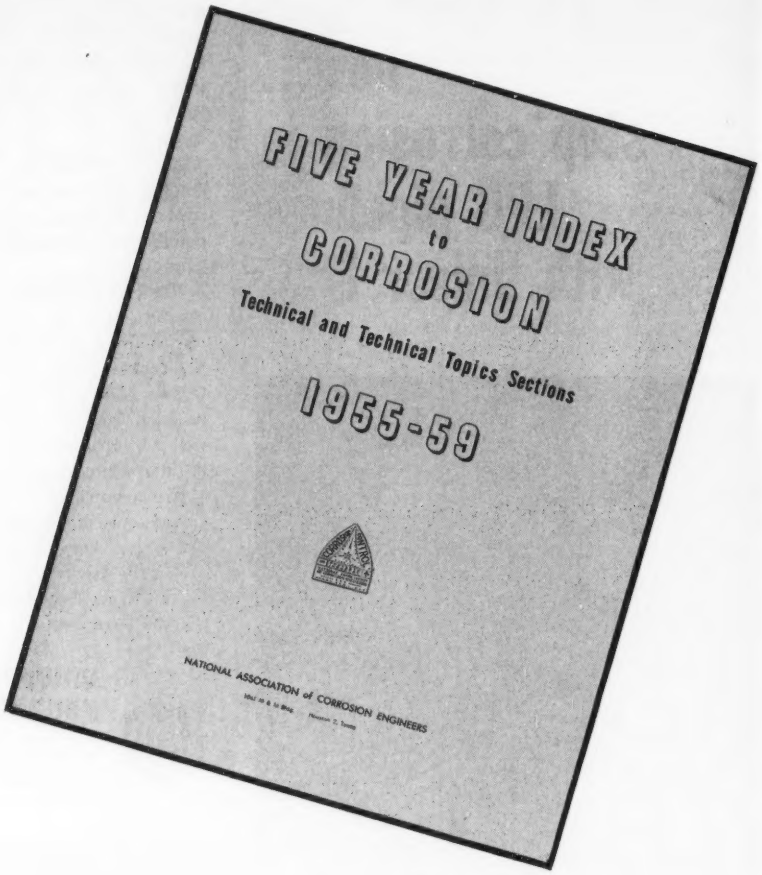

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Cast Alloys Better At High Temperature Than Wrought Alloys

Evidence indicating that cast alloys are more resistant to stress corrosion at high temperatures than equivalent wrought alloys is reported by Alloy Casting Institute, 1001 Franklin Avenue, Garden City, N. Y. The institute also reports that the belief that 18-8 stainless must be non-magnetic for maximum corrosion resistance is just an old metalworking tale.

Experiments at 1600 F have confirmed the relationship between grain coarseness and deflection resistance, the institute says. Specimen bars of type HT cast alloy (35% Ni, 15% Cr) were tested with similar bars of the equivalent wrought alloy (a special high carbon version of type 330 to match the normally higher carbon content of the cast alloy). Bending stresses were applied to both continuously over an extended period of time and the coarse grained cast alloy specimens exhibited considerably less deflection. An interesting check was run on this experiment: Some of the wrought type 330 alloy was melted and cast into test bars and run through the same procedure; these bars, now with typical cast grain structure, showed far greater resistance to deflection at 1600 F than the original wrought material.

Regarding the belief that 18-8 stainless must be non-magnetic for maximum corrosion resistance, the institute says this idea originated because the composition best for rolling is wholly austenitic and thus non-magnetic but that its lack of magnetism has nothing to do with corrosion resistance. In fact, some magnetism, indicating the presence of ferrite, is beneficial since ferrite improves resistance to stress corrosion cracking, the institute says. The no-ferrite limitation on wrought 18-8 alloys does not apply to cast alloys because ferrite does not affect their castability. In cast alloys tested, ferrite content was increased by careful control of constituent elements and a marked increase in stress corrosion resistance was observed, the institute reports.

Technical Topics Scheduled For October

Corrosion Resistance of Titanium, Zirconium and Tantalum Used for Chemical Equipment, by Clifford A. Hampel.

Laboratory and Field Tests on Titanium for Oil Field Pump and Valve Parts, by F. W. Jessen and Ricardo J. Molina.

Thermoplastic Pipe, Fittings and Equipment for Corrosion Control, by Russell W. Johnson and Allyn E. Webb.

RECORD and REPORT

Galvanic Corrosion Shuts Down Freeport's Salt Water Plant

A galvanic corrosion problem has shut down the Department of the Interior's $1,256,000 salt water conversion plant at Freeport, Texas. Carbon steel plugs in the heat exchangers failed because of galvanic corrosion, according to a plant official. The plant has been on stream continuously for only 60 days. Formal dedication ceremonies were held June 21.

Galvanic corrosion occurred where carbon steel plugs were used in heat exchangers having aluminum brass, admiralty metal or copper-nickel tubes. The plant has 12 heat exchangers or effects. Carbon steel plugs were used in all the exchangers, but galvanic corrosion did not occur in the five exchangers with carbon steel tubing. A total of 1700 plugs in the other seven exchangers are being replaced by the construction contractor, Chicago Bridge and Iron Company of Chicago, Ill. This work may keep the plant shut down for three or four weeks, according to plant officials.

Government specifications for the heat exchangers at the plant stipulated only the materials to be used for tubing. Design, selection of materials and fabrication of the remainder of the heat exchangers were left to the construction contractor, according to one plant official.

The corrosion failure was first detected August 1 when salt water was found in the fresh water side of one exchanger. Plant engineers luckily located the corrosion failure in the second unit checked. When galvanic corrosion was determined as cause of the leak, the plant was taken off stream to replace the carbon steel plugs in the other six exchangers although failure had not occurred in all of them.

Replacement plugs in each of the exchangers will be of the same metal as the tubes.

Design for a service life of 20 years, the salt water conversion plant has a capacity of one million gallons per day. Half of this is used by the City of Freeport to supplement its municipal water supply; the other half million gallons are used by Dow Chemical Company.

Architect-engineer for the plant was W. L. Badger Associates of Ann Arbor, Mich., who suggested the use of LTV (long tube vertical) evaporator design for a pilot plant built in 1957. The LTV design was used for the Freeport plant. Management and operating contractor for the Freeport plant is the Stearns-Roger Manufacturing Company of Denver, Colo.

Another Corrosion Problem

Another corrosion problem stemming from the salt water conversion plant, although not necessarily related to the galvanic corrosion failures on the plugs, has been occurring in the Freeport water system. Iron stains have been appearing in sinks and bath tubs of the city. These stains stopped forming when the salt water conversion plant was pulled off stream August 1 because of the corrosion failures, according to Freeport's city manager.

One theory to explain these iron stains was credited to "an informed source" by the Houston Post newspaper: that the lower mineral content of the water from the conversion plant is removing the rust scale inside the water distribution lines formed by the high mineral content water previously used by the city, which had 1100 ppm of dissolved solids.

Spaceship Nuts and Bolts To Be Developed for A.F.

Nuts and bolts that can hold spaceships together at 2000 to 4500 F are scheduled for development under a $350,000 Air Force contract awarded to Republic Aviation Corporation, Conklin Street, Farmingdale, L. I., N. Y.

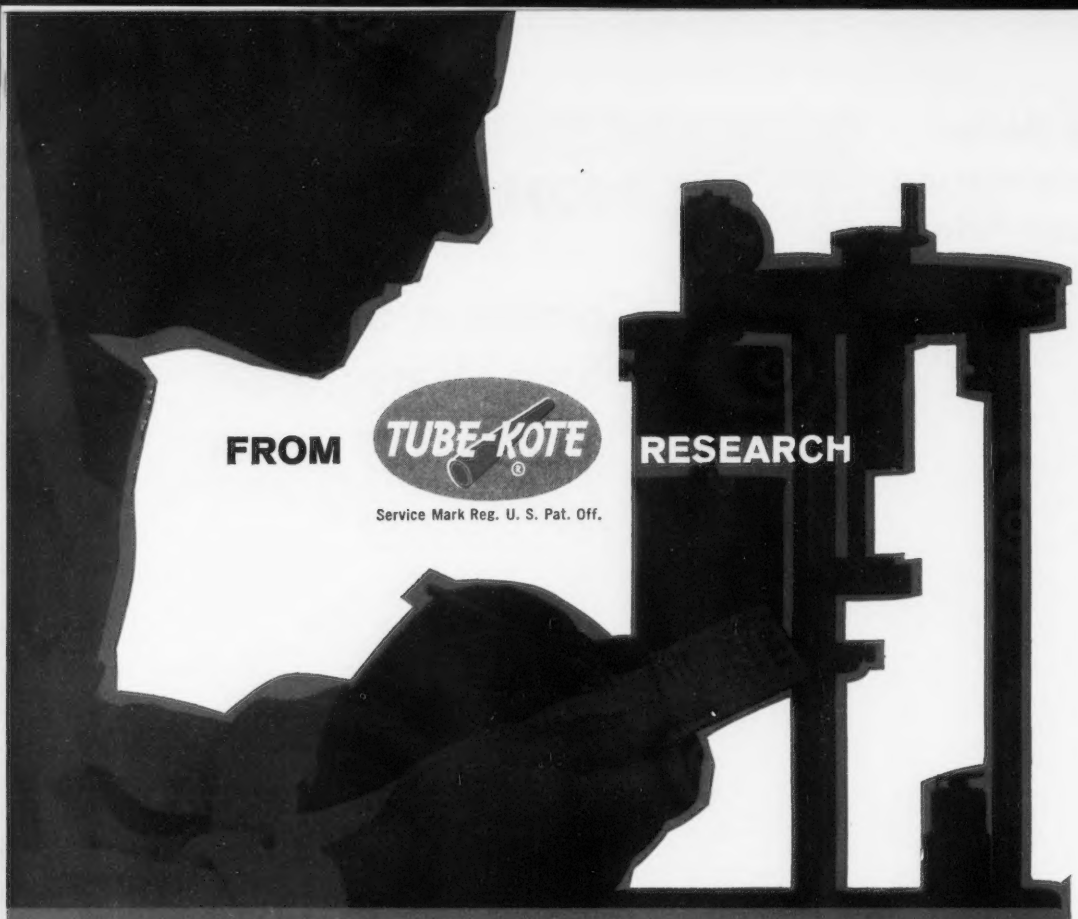
Republic's engineers plan to use alloys of molybdenum, columbium and tungsten to make fasteners that can withstand the stresses of space service such as oxidation at high temperatures and vacuum and radiation effects. Other critical design factors are acceleration, vibration, aerodynamic heating and internal heating and cooling.

U.S. Offers More Grants For Radiation Research

Research on radiation effects and controls is being stepped up by the government. Research grants in the field of radiological health are being offered to support the work of individuals, universities, hospitals, laboratories and other public and private institutions in the assessment and control of radioactive exposure.

Research proposals should contribute to the determination of the extent and character of the radiation problem as well as the mechanisms by which radiation produces damage, according to the government's news release.

Information regarding the program and grants is available from Paul F. Hahn, Chief, Office of Extramural Grants, Division of Radiological Health, U. S. Public Health Service, Washington 25, D. C.



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BOOK NEWS

Korrosionsshutz durch Anstrichstoffe. (Preventing Corrosion With Protective Coatings.) In German. By K. A. Van Oeteren. 1961. 456 pages, 6½ x 9¼ inches, cloth. Wissenschaftliche Verlagsgesellschaft MBH. Postbox 40, Stuttgart 1, Germany. Per copy DM 62.

A comprehensive treatise on the subject derived almost entirely from German and Western European sources. Contents include: Corrosion theory, prevention, cleaning and derusting, primers, coating techniques, testing, organization and administrative data, coatings for non-metals.

Appendices include data on economics, classifications of coating types, chemical resistances, a list of schools in which industrial coatings subjects are taught, including the subject and name of instructor; organizations concerned with industrial coatings problems; literature references, an alphabetical subject index and an author index.

Like nearly all German books it is beautifully printed. There are numerous illustrations and tables of data.

Fabrication of Welded Rocket Cases. 59 pages, 6 x 9 inches, paper. 1961. American Welding Society, 33 W. 39th St., New York 18, N.Y. Per copy $2.50.

A report of the AWS Missiles and Rockets Fabrication Committee containing the following information on rocket cases: Materials, design, welding, quality assurance. There are extensive tabulated data and illustrations.

Florida's Air Resources. 66 pages, 8½ x 11 inches, paper. February, 1961. Florida State Board of Health, Jacksonville, Fla. Price not indicated.

Comprehensive study of present and possible future air pollution in Florida and what is being done to eliminate the problem. Florida's climate, growth, major air pollution problems and management of air resources, present and future, are discussed.

Advances in Cryogenic Engineering, Vol. 6. K. D. Timmerhaus, editor. 662 pages, 6½ x 10 inches, cloth. 1961. The Plenum Press, Inc., 227 West 17th St., New York 11, N.Y. Per copy, U.S. $15; foreign $17.50

Consisting of 65 technical papers and discussion thereon presented at the 1960 Cryogenic Engineering Conference held by the University of Colorado and the National Bureau of Standards at Boulder, Col.

Major topical subdivisions are: Space technology, applications, superconductivity, processes, transfer phenomena, equipment, physical equilibria and related properties, heat transfers and thermometry and mechanical properties.

The diverse nature of the contents can be estimated from titles of some of the papers: Selection of cryogenic rocket insulation systems, spaceborne cryostats for continuous operation, superconducting magnets, bearing lubrication at low temperatures, design of piping for cryogenic fluids, infrared detector refrigerants, preliminary temperature-entropy diagram for neon, low-temperature

(Continued on Page 40)

PVC PLASTISOL will be used to coat corroded domestic liquefied petroleum gas tank in service in Hawaii. Isle-Gas, which supplies liquefied petroleum gas service to consumers on the islands of Oahu, Kauai, Maui and Hawaii and which has over 6000 tanks in service, has found plastisol coatings to be resistant to Hawaii's high humidity, salt air and trade winds.

Gas Firm in Hawaii Uses PVC Plastisol To Maintain Tanks

In Hawaii, a PVC plastisol coating is now being used to maintain over 6000 domestic liquefied petroleum gas tanks subjected to high humidity, salt air and constant trade winds.

Test tanks with PVC coatings have been in service for over 10 months without evidence of corrosion, according to the vice president of The Honolulu Gas Company, Ltd., the parent company of Isle-Gas Services Division which supplies liquefied petroleum gas service to consumers on the islands of Oahu, Kauai, Maui and Hawaii.

Also, in sunlight exposure comparison tests, comparing plastisol-coated tanks with conventional paint finishes over a zinc-base primer, the plastisol-coated tanks maintained lower internal temperature and desired pressure with 60 mils of material. Excessive insulation will drop tank pressure below an efficient level.

Soon after it was formed in the early 1950's, Isle-Gas became aware of the corrosion threat to its equipment. Prior to the use of the PVC coating, Isle-Gas tried maintaining tanks in the field using wire brushes and chipping hammers and red lead and tar as primers. But after several years it was evident that neither was effective: Blisters formed under the surface of the red lead-primed tanks and tar bled through the linseed oil-base finish.

Under the new PVC maintenance program, when it appears that corrosion may cause premature failure of a tank, the tank is replaced and taken to the gas company's repair facility in Honolulu. There the tank's serviceability is determined by a hydrostatic test at 1½ times the normal working pressure. If the tank passes this test, it is sandblasted, refitted as necessary and refinished.

Plastics Engineering of Hawaii, Inc., has been contracted by the gas company to apply the PVC coating which is standard green Unichrome 5300 spray applied plastisol produced by Metal & Thermit Corporation of Rahway, N. J.

Field coating is done also with the PVC. First the old coating is cut back beyond the corroded area. Then the exposed metal is wire brushed and after metal particles have been washed away with a solvent, a primer is applied followed by the plastisol coating. A portable heat gun is used to cure the coating.

Tokyo Store Tests Transistor Phones

An experimental transistorized telephone system has been in use at a Tokyo department store for the past year. It has worked so well that its use will be extended, according to four engineers of Nippon Electric Company, Ltd., Tokyo, who described the transistorized system to members of the American Institute of Electrical Engineers at a meeting held recently at Cornell University.

The 200-line system utilizing 2500 transistors and 9500 diodes was installed in the Mitsukoshi Department Store in March, 1960. Since that time it operated without serious trouble on a 24-hour basis, handling daily about 6000 outside and 3000 intra-office calls.

The telephones are equipped with 10 push buttons instead of conventional rotating dials.

ASM's Detroit Show Includes Symposium On Auto Corrosion

The American Society for Metals will hold its 43rd National Metal Congress and Exposition October 23-27 in Cobo Hall, Detroit, Mich. More than 275 exhibits, 200 technical papers and a materials comparison center are scheduled. Two corrosion symposia are included in the Engineering and Technical Programs.

The Engineering Program has five papers on corrosion. These papers which will be presented in two sessions Monday, October 23, are:

Corrosion in Automotive Applications (I), 9 a.m.

High temperature Corrosion by J. J. Moran and E. M. Skinner of International Nickel Co., Inc.

Evaluation of Materials for Automotive Exhaust Systems by L. M. Boguski of Republic Steel Corp.

Corrosion Properties of Low Alloy High Tensile Steels by Herbert Phelps of United States Steel Corp.

Corrosion in Automotive Applications (II), 2 pm

Galvanized Steel for Automotive Use by J. C. Widman of Ford Motor Company

Paint Systems for Corrosion Protection by Norman Price and C. O. Durbin of Chrysler Corp.

The corrosion symposium of the Technical Program is scheduled to begin Thursday, October 26, at 2 p.m. The four papers in this symposium are:

Morphology of Grain Boundary Carbides and Its Influence on Intergranular Corrosion of 304 Stainless Steel by R. Stickler and A. Vinckier of Westinghouse Electric Corp., Research Laboratories, Pittsburgh, Pa.

Corrosion Resistance and Mechanical Properties of Ti-Mo Alloys Containing Noble Metals by C. R. Bishop, Union Carbide Metals Co., Niagara Falls, N. Y., and Milton Stern, Linde Co., Indianapolis, Ind.

Investigation of Effects of Fabrication Variables on Corrosion Resistance of Zircaloy-2 by Herbert S. Kalish, Nuclear Fuel Research Laboratory, and Harold M. Cobb, Olin Mathieson Chemical Corp., New Haven, Conn.

Propagation of Stress Corrosion Cracking in a Magnesium-base Alloy as Determined by Several Techniques by W. M. Pardue, Battelle Memorial Institute, Columbus, Ohio, and F. H. Beck and M. G. Fontana, Ohio State University, Columbus, Ohio.

On Monday, October 23, as part of the Technical Program, a symposium on mechanical properties of steels will begin at 9 am. An interesting paper in this symposium is Noxious and Innocuous States of Hydrogen in Iron by Daniel Jean-Paul Adenis, Dow Chemical Co., Midland, Mich., and W. M. Baldwin, Jr., Case Institute of Technology, Cleveland, Ohio.

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BOOK NEWS

(Continued From Page 39)

thermocouple thermomometry, properties of 7000 series aluminum alloys at cryogenic temperatures.

There is an accumulative subject index for the first five volumes of the series (available from same publishers) but none for this volume. There is an author index and numerous illustrations, graphs and tables.

Progress Report of Florida Air Pollution Control Commission, January 1958-January 1961. 18 pages, 6 x 9 inches, paper. State Board of Health, Jacksonville, Fla. Price not indicated.

Industrial air pollution's harmful effects on Florida's plant and animal life are discussed. Also considered are nuisance odors, growth problems and the tourist trade. Control legislation is covered.

ASME Process Industries Meeting to Be in Houston

The American Society of Mechanical Engineers' Process Industries Conference will be held October 4-6, 1961, at the Shamrock Hilton Hotel, Houston, Texas. Ten papers are scheduled for the technical meeting, one of which is Use of Sewage Effluent for Process Needs by C. H. Connell of the University of Texas Medical School, Galveston, Texas, and M. C. Forbes of Aquatrol, Inc., Houston, Texas.

A trip will be made to Freeport to inspect the new municipal sea water conversion plant.

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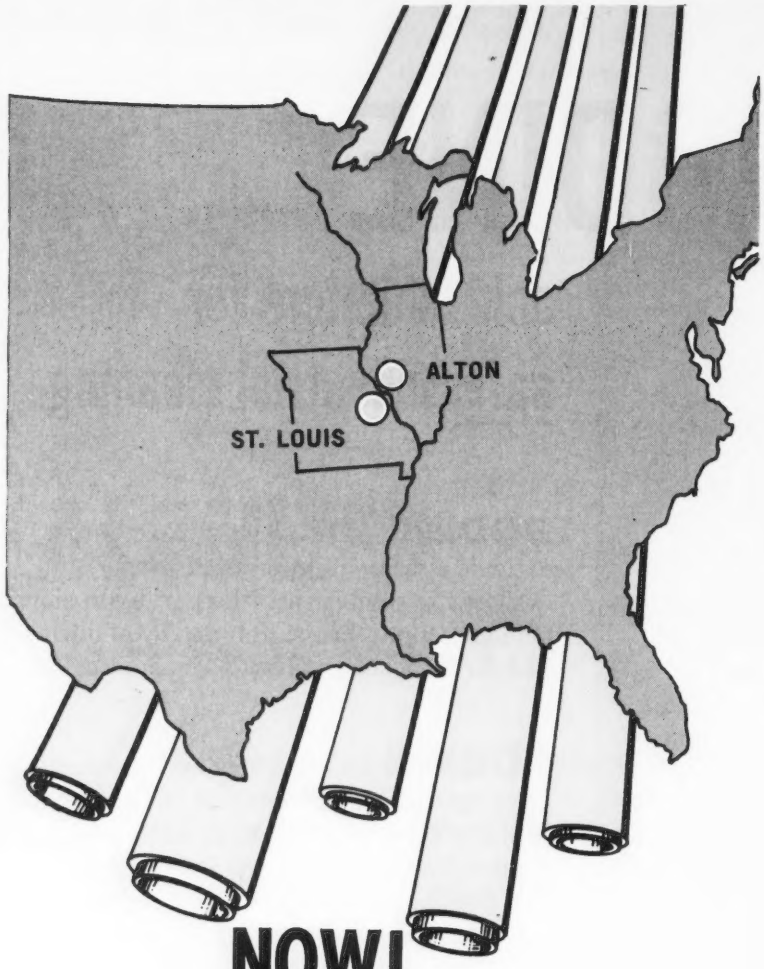

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New Corrosion Control Society Formed in France

An organization consisting of trade associations, technical centers, professional groups and research laboratories has been formed to coordinate corrosion control activities in France. To be known as "Centre Francais de la Corrosion" (Cefracor), it has a 27-member board of directors headed by Prof. G. Chaudron, University of Paris as president. Prof. Chaudron is CORROSION's overseas correspondent on corrosion activities.

Other officers include: Mm. Dechaux, Association des Ingenieurs en Anticorrosion; Ellefsen, Societe de Chimie Industrielle; Hache, Insitut de Recherches de la Siderurgie; LaCombe, Centre National de la Recherche Scientifique; Roger Mathieu, Federation des Peintures, Vernis et Sucres D'Imprimerie; Morizot, Chambre Syndicale des Producteurs D'Acier Fins et Speciaux;

Piganiol, Delegation du Commissariat a la Recherche Scientifique et Technique; Salesse, Centre D'Etudes Nucleaires and Roger Studler, Synducat National du Revetment et du Traitement des Metaux, vice-presidents.

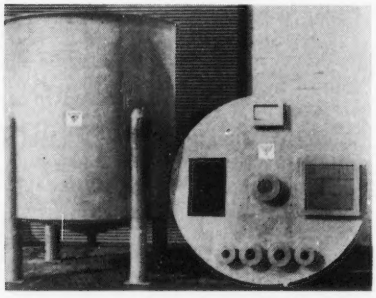
Honorary President is Prof. Portevin, a member of the Institute.

Among its activities will be liason with similar organizations abroad and conventions and meetings.

Aerojet-General Forms Company to Make Missiles

Aerojet-General Corporation has consolidated its Spacecraft Division and its subsidiary Space Electronics Corporation into a new company named Space-General Corporation. Space-General will design and develop complete missile and space systems.

A new plant will be built for Space-General on a 73-acre site in the Los Angeles area. Its first building, to contain 200,000 square meet, will be ready in early 1962. In the interim, the company will be headquartered at 777 Flower Street, Glendale, Cal.



CHEMICAL RESISTANT glass reinforced plastic mixing tank is used in the corn products industry to dissolve diethylaminoethylchloride and sodium aluminate in water. Complete structure, including flanged inlets, outlets, top and legs, is contact molded with glass mat and thermosetting resin. High strength top supports an agitator for mixing slurry. Coned bottom is designed to eliminate deflection when tank is full. Capacity of the tank is 2000 gallons. It is 9 ft. 6 in. high with a 6-ft. diameter and a ½-in. wall. It was designed and produced by The Ceilcote Company, 4832 Ridge Road, Cleveland 9, Ohio. Resin used is Ceilcote's Duracor 2000-5.

Standards Book Available

A new booklet detailing the work of the International Organization for Standardization, its technical committees and standards recommendations is available from the American Standards Association, 10 East 40th Street, New York 16, N. Y. The price is $4.80.

Published in conjunction with the ISO General Assembly meeting held in Helsinki in June, the first edition of the ISO Memento offers practical information regarding ISO activities and projects being considered.

The 64-page brochure also lists member bodies, administration of ISO and general information. The preface and technical committees are in English, French and Russian. The rest of the text is French and English in adjoining columns.

Fibreglass Ohio Acquired By White Sewing Machine

Fibreglass Ohio Inc. has been acquired in a stock transaction by White Sewing Machine Corporation, 11770 Berea Road, Cleveland 11, Ohio.

Production capabilities of Fibreglass Ohio will be combined with those of White's Apex Reinforced Fibre-Glass Division which produces filament wound pressure bottles and centrifugally molded tanks for military and commercial applications plus tanks, containers and material handling units for automotive and industrial uses.

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Wanted: Sales engineer to sell and service anodes for cathodic protection. Experience in the field desirable. Nationally known company with headquarters in Midwest. Send resume of education and experience. CORROSION, Box 61-21.

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Opening for Inspection Engineer at major multi-unit chemical plant in Central Illinois. Seek Ch. E., M.E., or Metallurgical Engineer, with 3 years or more experience in chemical or petroleum industry.

Position involves design review and inspection of piping and process equipment; maintenance inspection and corrosion data; and conduct related studies.

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To take charge of maintenance and repair division of major manufacturer serving chemical, petroleum and petrochemical industries. Requires graduate engineer with responsible contract maintenance experience with ability to negotiate contracts and build division. Salary open.

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Positions Wanted

Corrosion Engineer—M.S.Ch.E. Process design, heat transfer experience. Five years' research and development work on corrosion inhibitors, test equipment, refinery corrosion control, chemical suppliers' contacts. Married. Prefer East Coast area. CORROSION, Box 61-17.

Sales Manager, graduate chemist and chemical engineer. 16 years' experience in technical sales, production, research and development and material testing of coatings, sealants, reinforced plastics, sheet linings. Prefer East. Desire position with raw material supplier. CORROSION, Box 61-16.

Corrosion Engineer—BEE, 12 years' experience in oil, mining & consulting engineering operations at engineering and managerial levels. Desire supervisory position with growth potential. Resume on request. CORROSION, Box 61 - 19.

Engineer B.S.E.E., age 35, 11 years' experience in all phases of production, process plant, pipeline and gas distribution corrosion control. Desires responsible position with oil, gas or pipeline company. Will consider relocating. CORROSION, Box 61-18.

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Immediate career opportunity for an experienced corrosion chemist to take charge of a laboratory investigating corrosion problems in the fields of organic and inorganic chemistry. Position involves forward corrosion research, laboratory corrosion studies and supervision of one or two persons.

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Modern research facilities located near Finger Lakes and Adirondack recreational areas of New York State. Liberal employee benefits.

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Research engineers at INCO's Harbor Island (Kure Beach) Corrosion Laboratory carry on a continuous and comprehensive program of investigations in the vital field of marine corrosion and associated electrochemical phenomena on all materials.

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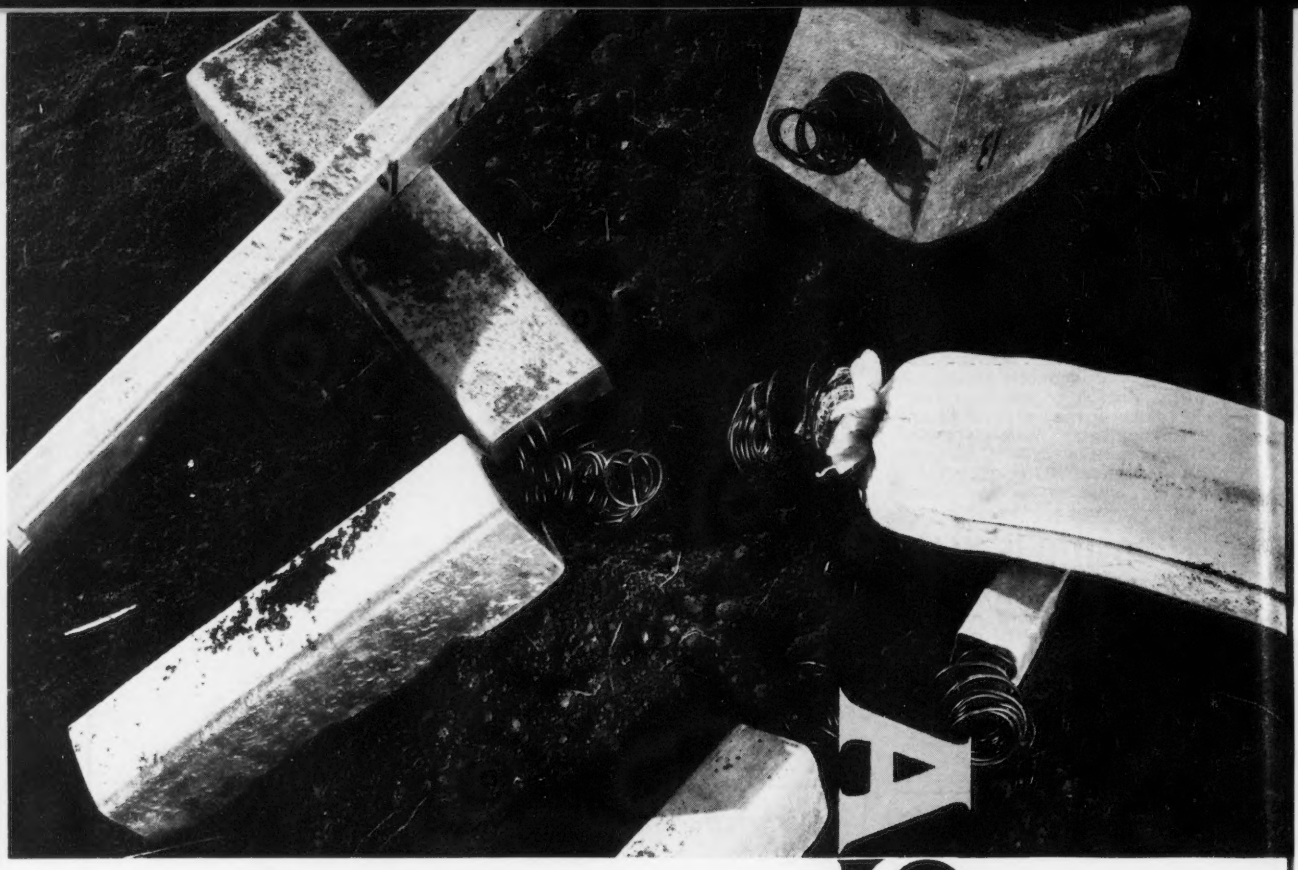

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and other non-ferrous protective materials

Federated galvanic anodes, specially designed to protect pipelines and other buried structures, are just one of the wide range of Federated materials to control corrosion. Federated's Corrosion Advisory Service can recommend the best for you . . . magnesium or zinc anodes; lead sheet, pipe, and fittings; zinc and zinc alloys for galvanizing; copper and aluminum alloys; and plating materials that include nickel, copper, lead, cadmium, zinc and silver anodes, nickel salts and addition agents for plating baths. For complete data, write or call—Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y. or a nearby Federated sales office.

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Fairfax 2-1802

BOSTON 16, MASS.
Liberty 2-0797

CHICAGO, ILL. (WHITING)
Chicago: Essex 5-5000
Whiting: Whiting 826

CINCINNATI, OHIO
Cherry 1-1678

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Chicago: Essex 5-5000

IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

PERIODICALS

European Shipbuilding—Journal of Ship Technical Society. (In English) Bimonthly, 56 pages, 8¼ x 11¾ inches. Vol. X, No. 2, 1961. Selvigs Forlag, Radhusgt. 8, Box 162, Oslo, Norway. $4.50 (U.S.) per year.

Issue contains resume of fundamentals of ship hull corrosion and methods of combating it. Three main articles are: Experience With Cargo Liners Fitted With Fast-Running Diesel Engines, Electronic Calculations for Launching of Ships and Cathodic Protection of Hulls and Related Parts, the last article being a NACE Technical Committee Report appearing in CORROSION, May, 1960.

Brochure & Subscription Price List on 363 Patent Subjects With Indexes. 1961. 11 pages, 8½ x 11 inches. Patent Intelligence File Company, 187 Olive St., New Haven 11, Conn. FREE.

Describes annual and back year illustrated patent digests available on subscription for 363 subjects indexed to coincide with U. S. Patent Office classifications. Average annual current subscription per subject is about $20. Back year patent digests per subject are made up in books for 5, 10 and 17 years, averaging $155, $280 and $435 respectively. Three indexes are furnished with back year books and annual subscriptions; these indexes are arranged according to (a) class and sub-class numbers and descriptions, (b) patent number by subclass numbers and (c) patent number by company names. Patent illustrations and briefs are shown in chronological order.

Publications of Illinois State Water Survey. January, 1961. 16 pages, 3½ x 8½ inches. Illinois State Water Survey, Box 232, Urbana, Ill. FREE.

Pamphlet lists bulletins, reports, circulars, reprints, contract publications and cooperative reports with State Geological Survey issued 1897 to 1961. Authors, prices and length are indicated. Publications cover research and service programs concerning available ground and surface water, quality of water resources, water usage, development of water supplies, siltation of reservoirs and meteorological factors closely related to water supply.

Pakistan Journal of Scientific and Industrial Research. (In English). Quarterly, 56 pages, 8¼ x 10½ inches. Vol. 3, No. 2, April 1960. 141-S/2, P.E.C.H.S., Karachi, 29, Pakistan. Price: 15 Rupees per year.

Nine main articles include biochemical and nutritional studies on East Pakistan fish, methods for estimating oil content of cottonseed, studies in relationship between viscosity and molecular structure and biosynthesis of some natural benzofurans and related compounds. A short communications section discusses method for commercially refining shark liver oil; eublemma amabilis; and essential fatty nutrients in diets and effects on health and on liver and heart degeneration in mice. Magazine contains a news section, which reports Pakistan's first steel mill will be at Karachi, and a book section with resumes of four foreign books.

Foam Glass to Insulate Liquid Gas Plant in Saudi Arabia

Foam glass is being used to insulate and protect from salt air corrosion the first plant specifically designed to liquefy propane and butane gas for shipment by refrigerated tankers.

At the Persian Gulf port of Ras Tanura, Saudi Arabia, where the temperature rises to 120 F, the Arabian American Oil Company is building its $7 million plant. When in production the plant will be able to supply 4,000 barrels per day of liquid propane and butane or a blend of the two to refrigerated tankers.

Three 70,000-barrel refrigerated steel tanks insulated and protected by foam glass will store the liquid gases. Liquid propane is stored at —43 F, liquid butane at 0 F.

The protective foam glass shell for the tanks is installed thus: First the walls and roof are primed with an asphaltic coating and two layers of foam glass blocks adhered with hot asphalt. Blocks are then coated with an asphalt cutback material in which a fibrous glass cloth is embedded. A final coating of asphalt cutback completes the outer finish. Also two layers of two-inch thick cellular glass blocks are incorporated into the foundations of the tanks. The foam glass blocks have ultimate compressive strength of over seven tons per square foot. Piping and equipment at the plant are insulated with two layers of two-inch foam glass topped with glass cloth.

The high strength foam glass is unaffected by most acids and solvents and impervious to moisture, according to its manufacturer, Pittsburgh Corning Corporation, One Gateway Center, Pittsburgh 22, Pa., which markets it as Foamglas. The strength of cellular glass allowed some cost savings by eliminating the need for a second outer steel shell that might have been required to protect other insulations, Pittsburgh Corning reports.

In the past these gases were maintained in a liquid state by high pressures. But by holding the gases at very low temperatures the same results can be achieved at much lower pressures. This procedure reduces the cost of pressure vessels which must have thick walls to withstand the higher pressures. For example, to realize the 210,000-barrel capacity soon available in the three refrigerated storage tanks at Ras Tanura, seven 30,000-barrel pressure vessels would be required at several times the cost of the refrigerated tanks.

At the new plant, two 765 hp compressors will liquefy the gas through compression and auto-refrigeration. The gas will be compressed to 250 psi, vaporizing it and condensing it with water to remove heat. From a series of flash towers and condensers it will be delivered via insulated piping to the three storage tanks where the —43 F and 0 F temperatures will be maintained by recirculating vapors back through the compressors, flash towers and condensers.

TWO LAYERS of two-inch thick cellular glass blocks are incorporated as insulation into the foundation of one of three refrigerated liquefied petroleum gas storage tanks being built by the Arabian American Oil Company at Ras Tanura, Saudi Arabia. Walls and top of nearly completed tank in background are insulated with two layers of the foam glass blocks covered with a fibrous glass cloth.

The Arabian American Oil Company is owned jointly by Standard Oil Company of California (30%), Texaco, Inc. (30%), Standard Oil Company of New Jersey (30%) and Socony Mobil Oil Company (10%).

Rilem—Bulletin of International Union of Testing and Research Laboratories for Materials and Structures. (In juxtaposed French-English). Publication schedule not indicated. 138 pages, 8½ x 10¾. New Series No. 10, March, 1961. Publicite RILEM. 12, rue Brancion, Paris XV°, France. Subscription fee per year is 50 Swiss Francs, for one issue 15 Francs.

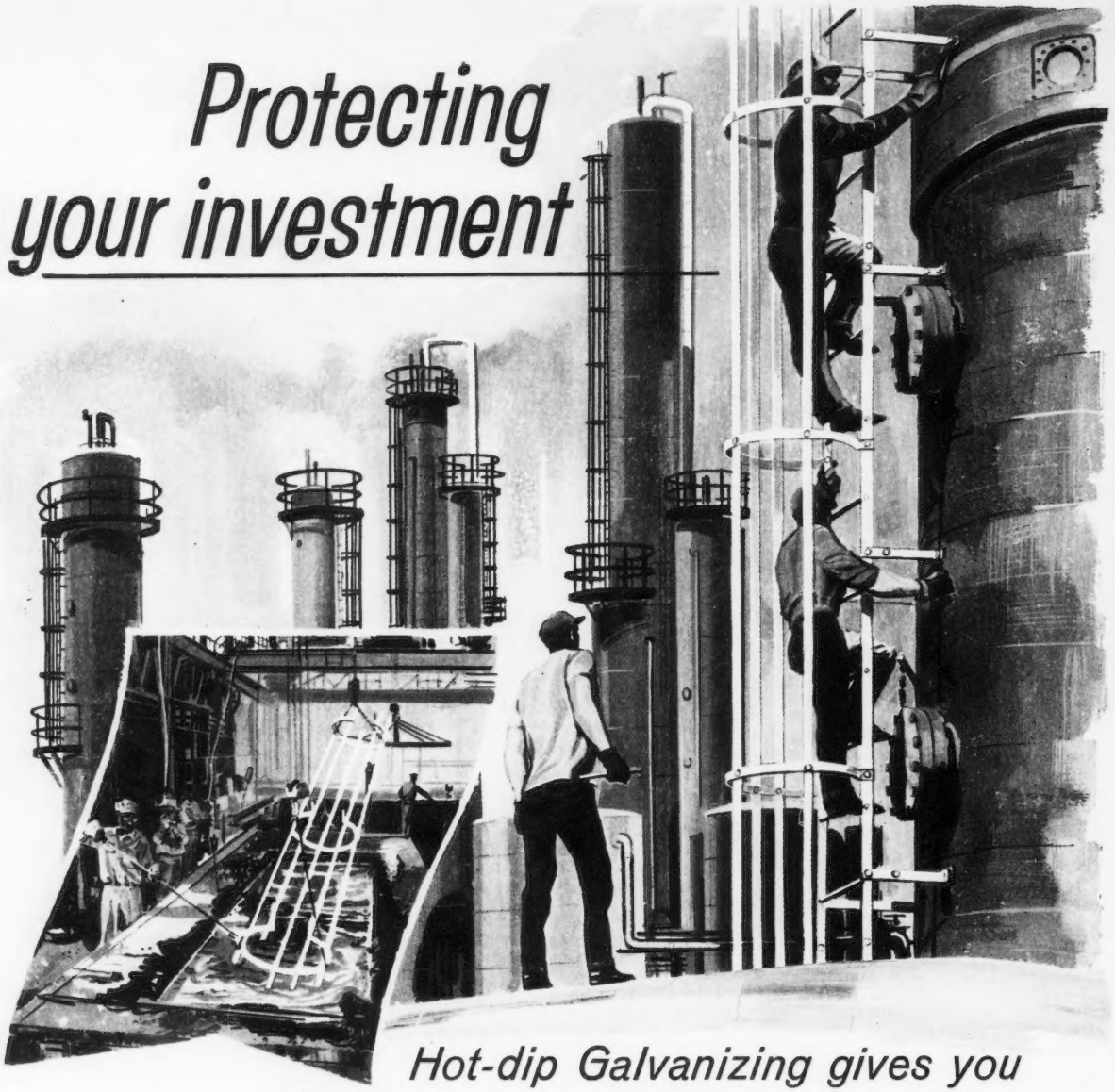
Proceedings of symposium on models of structures held at Madrid on June 22-26, 1959, 3d session, are reported in this issue covering such topics as use of plastic mouldings for ascertaining distortions under load, reduced scale resistance models of caissons made of prestressed concrete of G2 and G3 reactors, techniques used in structural engineering research and wires and tension arrangement for prestressing reduced models made of mortar.

Fe+Zn—Bulletin of European General Galvanizers Association. (In English) 8 pages, 8½ x 11¾. No. 1, Winter 1960-61. Zinc Development Association, 34 Berkeley Square, London, W.1., England. FREE.

Published for users of galvanized steel. First issue reports on progress in galvanizing, galvanized structures for buildings and the electrified Dutch Railways' extensive use of galvanized steel for its electrification equipment, switch covers,

(Continued on Page 47)

Protecting your investment



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Nowery J. Smith Co. also offers sand and shot blasting, metallizing, prime coating and painting, pickling, oiling, polyvinyl chloride PLASTISOL coating and other special protective coatings. We are exclusive in the Southwest for application of Goodyear Rubber Company's PLIOWELD Linings.

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PERIODICALS

(Continued From Page 45)

signal parts and bridge railings and fencing. A news section briefly describes and illustrates a number of unusual applications of galvanizing, including a galvanized religious cross and a 1,000-foot TV mast in England. French, German and Italian editions are published also.

Gas e Industria. (In Spanish). Monthly, 39 pages, 8 x 11 inches. Vol. 1, No. 1, April, 1961. Gas e Industria, Viamonte 1620, 5° piso, Buenos Aires, Argentina. Subscription for 10 issues is $9 (U.S.).

New magazine's intent is to publish current technology concerning all phases of production and uses of gas in chemical, manufacturing and motor industries. First issue's articles are Odorants and Odoration Methods; Gas Turbine Electrical Power Stations; and Realizations, Investigations and Plans of the State Gas Enterprise.

Bulletin of the Chemical Society of Japan. (In English). Monthly. 162 pages, 7¼ x 10¼ inches. Vol. 34, No. 2, March 1961. 5,1-Chome, Surugadai-Kanda, Chiyoda-ku, Tokyo, Japan. Price not indicated.

This issue includes one article in German. There are 44 titles covering material ranging from colloidal chemical studies of starching materials, optical properties of colored colloidal systems, through papers on inorganic chemistry, such as polarographic behavior of vanadium and iron in thiocyanate; and including articles on organic and biological subjects. A section of short communications is included also.

English Aluminum Group To Hold Anodizing Meet

In England, the Aluminium Development Association, with the University of Nottingham Department of Metallurgy, will hold a conference on anodized aluminum at the university September 12-14, 1961.

Fifteen papers by British and foreign authors will be presented. The papers, which are to be printed and distributed before the conference, are as follows:

Performance and properties of Anodic finishes by J. M. Perfect.

Control of Quality of Anodic Finishes by J. G. Simmons.

Current Trends in Materials for Anodising by J. W. Cuthbertson and J. C. Bailey.

Bright Anodised Aluminium Surfaces by B. A. Scott and H. M. Bigford.

Colour and Textures in Anodic Finishes.

Theory of Formation of Oxide Coatings on Aluminium by J. F. Murphy and C. E. Michelson.

Characteristics of Barrier Type Coatings for Electrolytic Capacitors by R. W. Franklin.

Study of Growth Process of Primary Films on Surface of Aluminium by H. Ginsberg and W. Kaden.

Anodic Finishes for Decorative Applications by T. E. V. Stephenson.

Anodic Finishes for Electrical Insulation by J. J. Lee.

Anodic Finishes for Wear Resistance by W. J. Campbell.

Theoretical Aspects of Electrolytic and Chemical Polishing by A. W. Brace and J. M. Kafe.

Theory of Dyeing Anodic Finishes by C. H. Giles.

Information concerning the conference and papers can be obtained from the Secretary, The Aluminium Development Association, 33, Grosvenor Street, London, W. 1., England.

Catawba River Power Plant UnderWay in North Carolina

When completed about 1965, the Cowans Ford hydroelectric project on the Catawba River in North Carolina will be the fourth largest plant in installed capacity in the United States.

It will have a storage capacity at full pond of 1,093,600 acre feet and a shore line of more than 500 miles. Its turbine and generators will be the largest east of the Rocky Mountains.

The Catawba River, running in the southern part of North Carolina and the northern part of South Carolina, has been the site of hydroelectric projects since the old Catawba Plant was constructed in 1904 to furnish electric power for a single 300-hp motor in the Victoria Cotton Mill at Rock Hills, S. C. Today there are 12 hydro plants and ten dams along a 220-mile stretch of the river. These plants utilize 779 feet of fall out of a total of 1,052. The Cowans Ford project with a head of 112.5 feet will increase the developed head to 893, essentially completing development of the river.

Joint wrapping of mill coated pipe is easy, fast and *sure* with Arno Pipe-Wrap Tape. Its inert polyethylene backing is moisture proof, non-conductive and resistant to soil acids and alkalis. Tough and stretchy. High-tack adhesive. Write for information and free test sample.

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The sure way ... the easy way ... the economical way to stop rust and corrosion on all ferrous metal parts! Unique "NO-WRAP" Discs, impregnated with special Volatile Corrosion Inhibitor, replace and actually *out-perform* costly, complicated wraps or coatings. Used by leading manufacturers, airlines, etc. for parts protection and storage.

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GAR-LINE PENTON TANK LININGS

for High-Temperature Corrosion Proofing

Can be applied to virtually any surface or contour to give superior, low cost protection against high-temperature corrosion. GAR-LINE Penton Tank Linings are replacing and outperforming more expensive materials in an ever-increasing number of applications.

Serviceable at temperatures up to 280°F, these efficient linings embody outstanding tensile strength, excellent dimensional stability and low water absorption. Chemically, they resist bleaching agents, solvents, plating solutions . . . in fact, all inorganic acids except fuming nitric and fuming sulfuric.

Applied by carefully selected and authorized applicators. The experience of these tank lining experts guarantees satisfactory GAR-LINE Penton installation, prevents expensive failure due to improper application. Approved applicators include:

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1107 Northeast 106th Street
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BITTNER INDUSTRIES, INC.
91 Diaz St., P. O. Box 10265
Prichard, Alabama

BUCKLEY IRON WORKS
21 Christopher St., Dorchester, Mass.

BUFFALO LINING & FABRICATING CORP.
73 Gillette Ave., Buffalo 14, N.Y.

CEILCOTE COMPANY, INC.
4832 Ridge Rd., Cleveland 9, Ohio

CHEMICAL PROOF OF SEATTLE
625 Alaska Ave., Seattle, Wash.

ELCHEM ENGRG. & MFG. LTD.
P. O. Box 249
Burlington, Ontario, Canada

ELECTRO CHEMICAL ENGRG. & MFG. CO.
750 Broad St., Emmaus, Penn.

THE FABRI-FORM COMPANY
P. O. Box 125, Byesville, Ohio

FLORIDA CORROSION CONTROL
P. O. Box 10082, Jacksonville 7, Fla.

THE FORTUNE COMPANY
1100 W. 37th St.—North
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1300 Walnut St., Camden 3, N.J.

STEBBINS ENGRG. & MFG. CO.
Watertown, New York

WILLOW RUN RUBBER COMPANY
12575 Haggerty St., Bellville, Mich.

Tailored to your specific needs, GAR-LINE* Penton** Linings can be applied to a variety of complex shapes as shown in these photos.

Investigate GAR-LINE Penton Tank Linings as the answer to your corrosion problems. For more information, contact the applicator nearest to you. Or, write for data on Penton; information also available on Teflon† linings for Anti-Stick or corrosive applications. Special Products Dept., Garlock Inc., P. O. Box 612, Camden 1, New Jersey.

*Garlock Registered Trademark
**Registered Trademark, Hercules Powder Company
†Registered Trademark, The DuPont Company

GARLOCK

Equipment Services NEW PRODUCTS Materials Literature

Filters

Plating bath filter systems equipped with epoxy pumps, titanium shafts and polypropylene filter chambers are manufactured by Sethco Manufacturing Corporation, 2284 Babylon Turnpike, Merrick, L. I., N. Y. Available in 50 to 2700 gph capacities, filters are claimed suitable for chromic acid to 200 F. Optional shafts and fittings of SS 316, titanium, Hastelloy B and C and glass epoxy are available for pyrophosphates, fluorborates and high chlorides to 250 F.

•

Self supporting saran filter towers for aerating waste water have been devised by Dow Industrial Service, Division of Dow Chemical Company, 20575 Center Ridge Road, Cleveland 16, Ohio. Cross-corrugated stabilized saran sheets 36 x 21 inches can be welded together to form honeycomb filter towers of almost any size. The wavy saran sheets distribute falling liquid wastes in thin films over large surface areas to which biological slime can adhere and provide a high percentage of void space for natural draft ventilation and waste flow. Marketed as Dowpac, the sheets are extremely resistant to all common acids and alkalies except strong ammonium hydroxide and are unaffected by most alcohols, esters, ketones and nitroparaffines, Dow says.

Instruments

Both holiday detectors and pipe locaters are now available from Tinker & Rasor, Box 281, San Gabriel, Cal., which recently acquired the Detectron Company, manufacturer of vacuum tube and transistorized pipe locaters.

•

New four-inch meter scale that indicates both amps and volts is now standard on Good-All Cathodic Protection Rectifiers. Designed to speed checking time and increase accuracy, the switching circuit single-switch operation provides lightning damage protection and cuts replacement costs in half, according to manufacturer, Good-All Electric Manufacturing Company, Ogallala, Neb.

•

Thermoelectric generators rated at 8 watts under atmospheric conditions of maximum severity are available as a power source for cathodic protection installations. Cathodic Protection Service, Houston has been designated exclusive sales outlet for Cathodic Protection Applications of the devices made by Texas Instruments, Inc. The generators, using a lead telluride semi-conductor power element and natural gas, propane or butane as fuel, have an efficiency of about one percent. Applications of the device, designed for unattended operation for periods of six months or more, at locations remote from regular electrical service are expected to be extensive. Generators with larger capacities are being designed and will have the same characteristics. A data sheet is available on request.

Insulation

Heat reflective glass cloth-aluminum foil tape capable of withstanding temperatures to 600 F and radiant heat to 3000 F for short periods is reported by Minnesota Mining and Manufacturing Co., 900 Bush Avenue, St. Paul 6, Minnesota. Developed for missile and aircraft electrical control cables, wire harnessing, circuits, piping and pump valves, the tape has been used on the Titan missile and for Project Mercury, 3M reports, shielding parts from flaming rocket exhaust radiation during launch to burnout, a period of one to two minutes, at temperatures over 3000 F. Tape is a lamination of .0005-inch aluminum foil and .002-inch glass cloth coated with a white silicone adhesive. It is available in ¼ to 36-inch widths in 36-yard rolls.

•

High voltage cable insulation of butyl-base rubber risistant to 90 C, ozone and

(Contiued on Page 50)

Practical ideas to help you Stop CORROSION

ARE YOU GETTING THE MOST FOR YOUR MAGNESIUM ANODE DOLLAR?

Many corrosion engineers are concerned over the composition specifications of magnesium anodes used to stop corrosion on pipe lines, oil well casing, etc.—and rightly so. But there is a more important factor that is sometimes overlooked. This is the *actual weight* of the bare anode, particularly in backfill-packaged units.

During the past several years an increasing number of the companies that use anodes have found it pays to spot check the metal weight of all anodes purchased. Often the small cost of pulling the anode from the packaged backfill has been worthwhile. 17-pound anodes have been found to weigh as little as 14 pounds, 32-pound anodes from 26 to 30 pounds, and 50-pound anodes only 44 pounds.

We at CSI feel that, regardless of the supplier, a spot check should be made of all anodes purchased. Of equal importance, requests for quotations and the subsequent purchase orders should *define all specifications.* As far back as 1945, the industry set maximum weight deviations for bare magnesium anodes at ±3 per cent of the designated weight. We suggest that, if this condition is specified and checked, you will be getting more for your magnesium anode dollar.

You'll find it to your advantage to check with CSI for engineering and installation services, and for quality supplies for both anode and rectifier installations. Estimates or competitive quotations without obligation. Let our stock-holder-employees demonstrate the economical and satisfactory service they can give you. Call or write today.

CSI

Cleveland 13, Ohio
1309 Washington Ave.
Tel. CHerry 1-7795

CORROSION SERVICES INCORPORATED
General Office: Tulsa, Okla.
Mailing Address:
Box 787, Sand Springs, Okla.
Tel. Circle 5-1351

NEW PRODUCTS

(Continued From Page 49)

moisture is described in a 48-page manual available from manufacturer, The Okonite Company, Passaic Street, Passaic, N. J. Insulation is specified for direct burial, underground duct, interior, aerial and submarine cables. Electrical capacities, dimensions, various designs and protective coverings for various environments are discussed in the catalog.

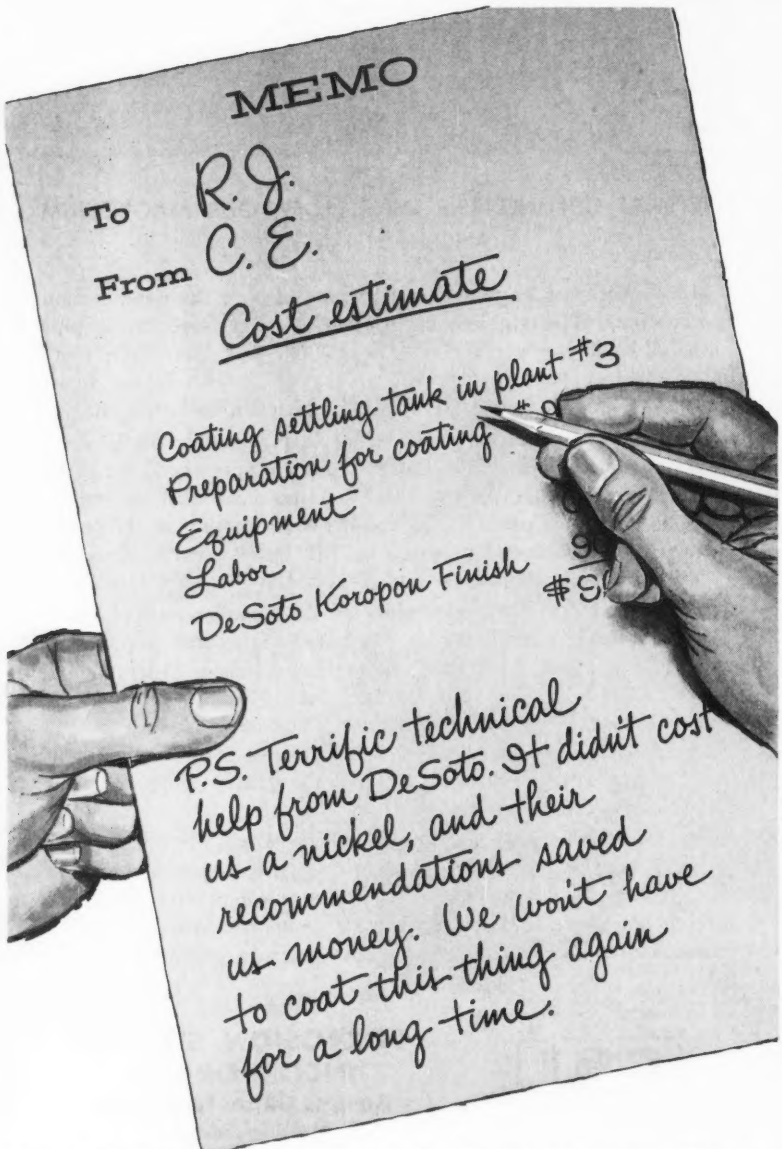
See Page 64 For NACE President Greco's News Letter

Metals, Ferrous

High temperature, high strength steels and alloys manufactured by Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa., are covered in a booklet available from the company. These metals are classified as iron base, nickel base, iron-nickel base, cobalt base and cobalt-chromium-iron-nickel alloys. Properties and test procedures are described.

•

Martensitic, austenitic and semi-austenitic precipitation hardenable stainless steels produced by Republic Steel Corporation, 1441 Republic Building, Cleveland 1, Ohio, are described in a 32-page booklet available from Republic. Precipitation hardening process of solution treatment, rapid cooling and controlled reheating is discussed together with applications and properties of the grades.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From C.E.
Cost estimate
Coating settling tank in plant #3
Preparation for coating
Equipment
Labor
DeSoto Koropon Finish
P.S. Terrific technical help from DeSoto. It didn't cost us a nickel, and their recommendations saved us money. We won't have to coat this thing again for a long time.

De Soto Chemical Coatings, Inc.
1350 SOUTH KOSTNER AVENUE CHICAGO 23, ILLINOIS

Metals, Non-Ferrous

High purity closely screened nickel powders are marketed by Sherritt Gordon Mines Limited, 25 King Street West, Toronto 1, Canada. Available in eight sizes from —50/100 to —500 mesh and in lots of 10, 100, 500 and 2000 pounds, the powders, Sherritt says, are widely used where corrosion resistance is needed in porous structures such as those used for filtering both liquids and gases. They are also said to show promise in fuel cell electrode applications, particularly hydrogen-oxygen fuel cells using potassium hydroxide electrolyte.

•

Ductile as-cast molybdenum produced by reducing molybdenum sulfide with tin is reported by Oregon Metallurgical Corporation, Albany, Ore. Working under a Bureau of Weapons contract, the company says its pilot plant operations have produced a 100 lb vacuum-arc-cast ingot with less than 20 ppm carbon, oxygen and nitrogen and less than 50 ppm sulfur. Tensile coupons cut before the ingot received any mechanical working had these properties: 37,000 psi yield strength, 46,000 psi ultimate tensile strength, 3.5 percent elongation in 4D and 3.2 percent reduction in area at room temperature.

Miscellaneous

Powdered ammonium metatungstate for use in preparing tungsten catalysts is available in commercial quantities from Sylvania Electric Products Inc., 730 Third Avenue, New York 17, N. Y. Sylvania cites petroleum refining industry as a potential user in producing reforming catalysts capable of converting low quality hydrocarbons boiling in the gasoline range into high quality products possessing anti-knock characteristics. The chemical is also potentially useful for electroplating solutions and for reactions such as oxidation, hydroxylation, hydrogenation and polymerization, Sylvania says.

•

A machine which cuts metallurgical specimens by an electric spark is marketed by Jarrell-Ash Company, 26 Farwell Street, Newtonville 60, Mass. This cutting method produces a smooth, strain free surface, the company says, and is very useful in preparing thin wafers for electrolytic thinning and transmission microscopy.

•

An organometallic chemical compound, bis (tri-n-butyltin) oxide, that exhibits control of fungi, bacteria, algae and marine organisms is described in a bulletin from Metal & Thermit Corporation, Rahway, N. J., which markets the compound as TBTO. Unformulated, it is a water insoluble liquid with a marked affinity for cellulose and thus is especially useful as a wood preservative in marine environments, M&T reports. Suggested uses are in control of paper mill slime, algae and fungi in industrial cooling systems and mildew of plastic and paper surfaces and in anti-fouling paints and textile treating.

•

Air compressors for automotive, industrial and contractor applications manufactured by Lincoln Engineering Company, 4010 Goodfellow Blvd., St. Louis

(Continued on Page 52)

NATIONAL
TRADE-MARK

GRAPHITE ANODES ARE BEST!

FOR LOW COST...

"National" graphite anodes provide ample conductivity for economical ground bed design in both low and high resistance soils. Installed with graphite particle or coke backfill, "National" anodes offer low initial cost; exceptionally long life.

National Carbon manufactures a complete line of anodes providing the economies of graphite to all types of cathodic installations.

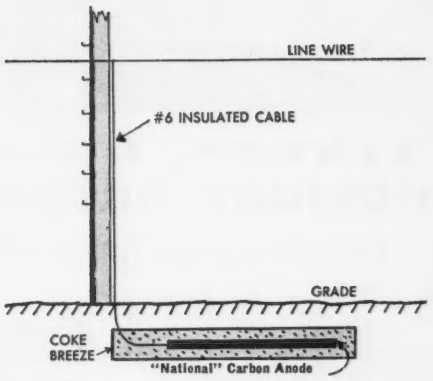
3″ x 60″ and 4″ x 80″
sizes in plain and NA Graphite

3″ x 30″ and 3″ x 60″
NA Graphite Anodes with Type QA Connections

2″ x 12″, 2″ x 20″ and 3″ x 30″
Type QA Anodes of NA Graphite

If you do not use "National" Graphite Anodes for cathodic protection, try them! We believe you'll find
"NATIONAL" GRAPHITE ANODES ARE BEST
FOR LONG LIFE AND LOW COST!

FOR LONG LIFE...



Since 1943, a distributed "National" carbon anode system has protected 2042 feet of 4 inch bare steel main for a large Eastern utility company. Installed horizontally (see diagram) to avoid shale rock, 16 — 2″ x 80″ anodes are spaced approximately 120 feet apart to obtain uniform protection.

Before installation of the "National" carbon anodes, 4 leaks occurred on the main in one year. Since cathodic protection began in October, 1943, there has not been a single leak.

• • •

INSTALLATION DATA

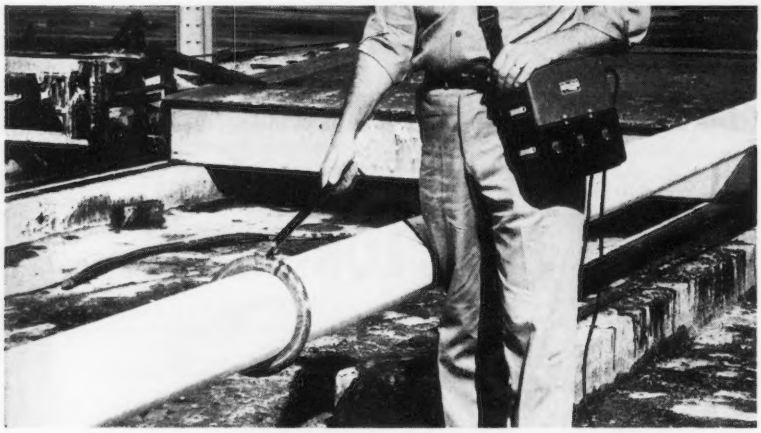
Anode size: "National" 2″ x 80″ Carbon
Backfill: Coke breeze
Length of anode service: 15-30 ampere-years per anode
Average soil resistance: 1000 to 10,000 Ohm. cm.

"National" and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY
Division of Union Carbide Corporation . 270 Park Avenue, New York 17, New York
IN CANADA: Union Carbide Canada Limited, Toronto

UNION CARBIDE

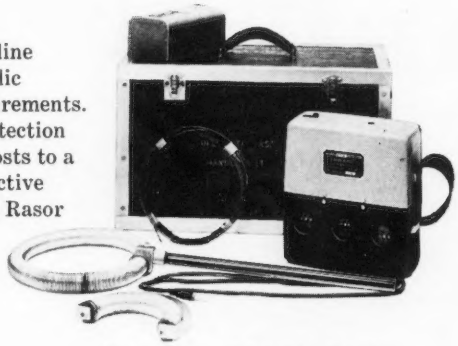
INSPECTION IS THE KEY TO GOOD PIPE COATING



TINKER & RASOR HOLIDAY DETECTORS

insure coating continuity

Every void in your pipeline coating increases cathodic protection current requirements. To obtain maximum protection and hold maintenance costs to a minimum, inspect protective coating with a Tinker & Rasor Holiday Detector and make repairs before backfilling.



Tinker & Rasor E P Holiday Detector.
Portable, "damp-climate" pulse type.

Write for your free Data Kit.

Tinker & Rasor has prepared a complete data kit of descriptive material and recommended procedures for inspecting protective coatings. Material includes technical data on equipment, recommended inspection procedures, general discussion of types of detectors, theory of operation, etc.

ENGINEERING NOTE:
To insure a perfect application, include Tinker & Rasor Holiday Inspection. Write for specification guide.

Quality Control for Coating Application

TINKER & RASOR

417 Agostino Road, P.O. Box 281 • San Gabriel, California

NEW PRODUCTS

(Continued From Page 50)

20, Mo., are covered in a 16-page catalog available from the company. Catalog lists over 200 gasoline and electric driven models featuring automatic start and stop and constant running units.

•

Burs and fins can be removed from hypodermic needles and other small metal parts with a tool that propels abrasive particles in a gas stream at 1100 fps. Designed for cutting or abrading hard, brittle materials such as ferrite, silicon and germanium and for cutting shapes out of tungsten sheet, the tool is manufactured by Airbrasive Department, S. S. White Industrial Division, 10 East 40th Street, New York 16, N. Y.

•

A new 35 mm microphotographic camera automatically determines exact exposure for metallurgical samples and biological specimens. Designed to fit any microscope, the camera has both built-in detail and field integrating exposure mechanisms; these are operated by two push buttons. Camera has interchangeable cassettes to hold type of film desired. The camera was developed by Ernst Leitz GmbH of Wetzlar, West Germany, and shown in the United States by E. Leitz, Inc., 468 Park Avenue, South, New York, N. Y.

Plastics

A new thermoplastic resin which remains flexible and tough at liquid oxygen and liquid hydrogen temperatures is reported by Minnesota Mining and Manufacturing Company, 900 Bush Avenue, St. Paul 6, Minn., which plans to market the resin as Kel-F 81 in the near future. Important qualities of products made from the resin, 3M says, include thermal stability from —400 to 400 F, abrasion resistance, resistance to a wide range of chemicals, fuels and other corrosives, excellent electrical properties, infrared transmission and zero moisture absorption.

•

Two new FEP-fluorocarbon resins, one for injection molding of coil forms, electronic insulators, seals and bushings, the other for use as a coating impregnant for glass fabrics, yarns and sleeving, are marketed by E. I. du Pont de Nemours & Company, Wilmington, Del. Rated for continuous service to 400 F, these resins, Du Pont says, are immune to chemical attack, have excellent electrical insulating, anti-stick and nonfrictional characteristics and will not absorb moisture. Teflon 110 is for injection molding; Teflon 120 is the water base dispersion, containing approximately 55 percent FEP solids.

•

Weather resistant thermoplastic acrylic sheet that can be punched or stamped to intricate shapes is marketed as Tuffak by Rohm & Haas Company, Washington Square, Philadelphia 5, Pa. This tough, flexible craze resistant sheet is available in colorless 42 and 84-inch squares .050 thick. Stamping at 90 F with punch and die sets equipped with stripper plates is recommended production technique. A suggested use is as

a glazing material installed by conventional calking methods or riveted or nailed to a frame. It also can be cold formed to glaze curved surfaces.

•

Cast acrylic lighting shields used in internally lighted outdoor signs and as light diffusers for interior lights are produced in 36 by 48-inch to 72 by 96-inch panels 0.060 to ⅜-inch thick by The Borne-Lite Corporation, 6731 Columbia Park Road, Landover, Md. Cast from Monocite methacrylate monomer manufactured by E. I. du Pont de Nemours & Co., Wilmington 98, Del., panels are available in clear, yellow, red, green, blue, black, transparent gray, white and translucent white.

•

Polyethylene drum faucets designed to dispense chemicals, detergents and waxes are available from Rieke Metal Products Corporation, Auburn, Ind. Alathon Polyethylene resin formulation is said to contribute stress crack resistance, toughness, flexibility and resistance to corrosion and discoloration.

Pumps

New frame mounted graphite pumps with 1, 1½ and 2-inch discharge openings have been introduced by National Carbon Company, 270 Park Avenue, New York 17, N. Y. Called Type F pumps, they supplement frame mounted Type C pumps with discharge openings of 2, 3 and 4 inches.

•

Cradle mounted centrifugal pumps constructed of either cast iron or stainless steel and designed for chemical service are described in brochure available from manufacturer, Ingersoll-Rand Company, 11 Broadway, New York 4, N. Y. Specifications include three models with discharge sizes from ¾ to 4 inches, delivery capacity to 1000 gpm and heads to 240 feet. All pump casings are of vertically split design. Flanged suction and discharge connections are standard on casings.

•

Monel and Inconel pump parts for corrosive service are covered in pamphlet available from Huntington Alloy Products Division, The International Nickel Company, Inc., Huntington 17, W. Va. Entitled "Practical Answers to Pump Problems," it relates specific applications where the alloys were used to overcome corrosion problems.

Safety

Hydrocyanic acid, its properties and recommended safe handling and use practices are described in a chemical safety data sheet available for 30 cents from Manufacturing Chemists' Association, Inc., 1825 Connecticut Avenue, N. W., Washington 9, D. C. Pamphlet, SD-67 (revised), details fire and explosion hazards and discusses employee safety education and training, including first aid, and personal protective equipment recommended for handling the acid. Storage practices, tank and equipment cleaning and repair methods and waste disposal also are covered.

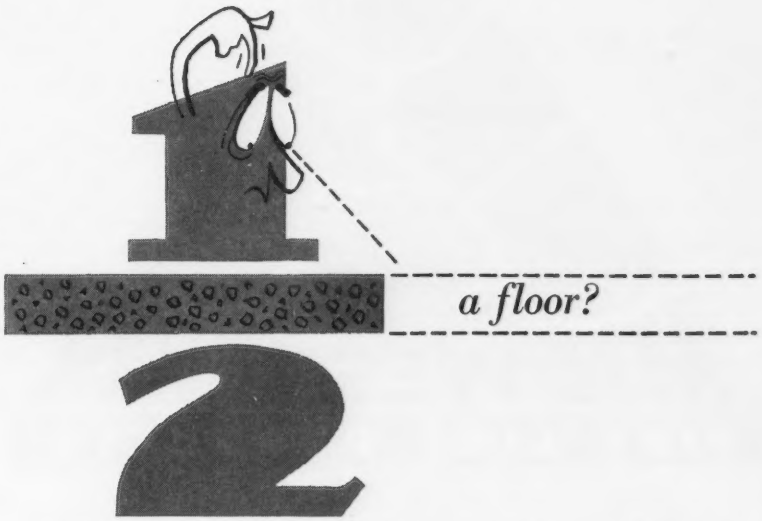
•

Industrial gas masks with seamless leakproof canisters are manufactured by Mine Safety Appliances Company, 201

(Continued on Page 54)

Why pay **FULL** *price*

for only



CEILCOTE CORROSION-PROOF MONOLITHIC FLOORING GIVES YOU GUARANTEED PERFORMANCE!

INSTALLATION AND MATERIALS ARE EQUALLY IMPORTANT!

You can't buy a bucketful of corrosion-proof flooring! The success of any flooring is determined by correct installation techniques as well as quality materials. Only Ceilcote offers you a *complete flooring service* . . . Corocrete monolithic flooring plus performance guaranteed installations. And Corocrete is scientifically formulated with the proper balance of resins, special aggregates and hardeners to meet your specific requirements!

INSIST ON THIS COMPLETE PACKAGE!

Ceilcote provides corrosion engineers to analyze your problems . . . produces the correct grade of Corocrete . . . prepares the surface and installs the flooring . . . all under one contract! Available with finishes ranging from non-skid to polished surfaces, Corocrete floors resist acids, alkalis, impact . . . are engineered to withstand thermal shock and expansion without cracking or spalling.

PROFIT FROM CEILCOTE'S EXPERIENCE!

Ceilcote offers you 33 years of experience in developing, manufacturing and installing reliable corrosion proofing materials for industry.

WRITE TODAY FOR COMPLETE INFORMATION

CEILCOTE

THE CEILCOTE COMPANY, INC.

8821-CC

The Ceilcote Company
4874 Ridge Road
Cleveland 9, Ohio

Please send me complete information about your complete flooring service.

Name_____

Company_____

Street_____

City_____ Zone_____ State_____

the line of MOST RESISTANCE

PIPE LINE PRODUCTS

■ *Midwestern's line of corrosion-resistant products offers you the most completely engineered materials in the pipe line industry. Every Midwestern product is backed by years of successful performance under the toughest field conditions. The Midwestern Line includes* **KERMAC** *outerwrap . . .* **KEYSTONE** *asbestos felt . . .* **KAPCO** *rock shield . . .* **COROMAT** *underground wrap . . .* **GLASFAB** *handwrap . . . and* **POLYKEN** *tape coatings.* ■ *Midwestern's sales representatives are your line of most assistance in providing the materials you require for solving your particular pipe corrosion problems. Through long experience, they are thoroughly qualified to meet your needs, regardless of the application specified. Call your nearest Midwestern representative TODAY . . . he'll respond quickly—and at your convenience!*

MIDWESTERN
PIPE LINE PRODUCTS CO.
4645 Southwest Blvd. Tulsa, Okla. HI 6-6144
Cable Address. Mid Pipe

branch offices
- Durham, N. C.
- Houston, Tex.
- Chicago, Ill.
- St. Petersburg, Fla.
- Pittsburgh, Pa.
- Oklahoma City, Okla.
- Des Moines, Ia.
- New York, N.Y. (export)
- Caracas, Venezuela

NEW PRODUCTS

(Continued From Page 53)

North Braddock Ave., Pittsburgh 8, Pa. Each canister is equipped with a toxic dust filter which, together with appropriate chemical fill, permits its use in atmospheres containing both gaseous and particulate contaminants. Face piece provides panoramic vision and a speaking diaphragm.

Tubing

Two new grades of postformable Micarta tubing are marketed by Westinghouse Electric Corporation, Micarta Division, Hampton, S. C. One grade (HY-370) is paper based, the second (HY-371) is cloth based. Both are said to be sufficiently thermoplastic for postforming when heated at 135 to 150 F for five minutes. Compressive strength of tubing is 18,500 psi for paper grade and 23,300 psi for cloth grade. Water absorption is 2.1 and 0.8 percent respectively. Short time dielectric strength is 700 and 341 volts per mil. Inside diameters range from ⅛ to 1 inch and wall thicknesses from 1/32 to 3/16 inch. Maximum length is 46 inches.

•

Pinholes and thread leaks in tubing are sealed by a sodium silicate solution which hardens to a glass-like lining when pumped into tubing, according to the manufacturer of the sealer, Dowell Division of The Dow Chemical Company, Box 536, Tulsa, Okla. Pulling the tubing to apply sealer is not necessary. Recommended uses are in both dry gas and distillate wells. It is most effective on leaks around poorly made up joints or joints with imperfect threads, Dowell reports.

•

For steam and other high temperature liquid service, flexible Teflon hose with either bronze or stainless steel braid is marketed by Resistoflex Corporation, Roseland, N. J. Hose is rated to 250 pounds of pressure for steam service and to 500 psi and 500 F for general service. Sizes range from ⅛-inch male pipe thread and fitting to 1-inch male pipe thread.

Water Treatment

A new water treatment method for small cooling towers and evaporative condensers is claimed by L* A Water Conditioning, Inc., 1007 Air Way, Glendale, Cal. Company says proper treatment results from a pre-treater utilizing a solid stick of chemicals and other features. Company will furnish product brochure on request.

•

A corrosion resistant feeder for adding chemicals to water systems is covered in a product data sheet available from Hagan Chemicals & Controls, Inc., Hagan Center, Pittsburgh 30, Pa. Unit includes positive displacement diaphragm pump, a 55-gallon polyethylene tank and a plastic dissolving basket. Pump feeds 2.4 to 24 gallons per day at zero psi and 2 to 20 gallons at 100 psi. The chemical head, connectors and pump body are high impact plastic, Hagan says.

MEN in the NEWS

Miles N. Clair, president of The Thompson & Lichtner Co., Inc., Brookline, Mass., has been elected president of the American Society for Testing Materials.

•

NACE Member **J. M. Bates** has been named senior staff engineer in the Engineering Department of Union Carbide Chemicals Company, South Charleston, W. Va.

•

John A. Barclay has joined The Lionel Corporation, Hoffman Place, Hillside, N. J., as vice president for research and development. **Walter K. Volkers** has been elected president, director and chief executive of the Lionel Electronic Laboratories.

•

NACE Member **M. C. Belz** has joined Ralph V. Rulon, Inc., Philadelphia 40, Pa., as head of Rulon's Johns-Manville Mastic activities.

•

Tinker & Rasor has appointed **Don R. Shannon** of D. R. Shannon Co., 1510 Rainier Ave., Seattle 44, Wash., as its distributor throughout the Northwest and Alaska.

•

Miss Thelma Hoffman has retired as chief librarian at Shell Development Company's Emeryville Research Center, Emeryville, Cal. **Roger M. Martin** is her successor.

•

Peter Payson, assistant director of research with Crucible Steel Company of America, Pittsburgh, Pa., received an honorary Doctor of Engineering degree from Stevens Institute of Technology in Hoboken, N. J., during the 89th Annual Commencement.

•

Charles W. Walton has been appointed vice president for research by Minnesota Mining & Manufacturing Company, St. Paul, Minn.

•

National Research Corporation, 70 Memorial Drive, Cambridge 42, Mass., has promoted **Maurice L. Torti** to director of metallurgical research for the Metals Division. **Christopher J. B. Fincham** has been appointed technical director of the division.

•

Albert J. Phillips of South Plainfield, N. J., vice president and director of research, American Smelting and Refining Company, has been named to present the fourth Extractive Metallurgy Division Lecture at AIME's 91st Annual Meeting in New York City in February, 1962.

•

NACE Member **Leo C. Mueller, Jr.,** has been promoted to vice president in charge of sales of Steele & Associates, Inc., 1405 Dutch Valley Place, N. E., Atlanta 9, Ga.

•

NACE Member **Charles E. Tirrell** has joined Chemionics Engineering Laboratories, Inc., One Bala Ave., Bala-Cynwyd, Pa., as chief research scientist. **Howard H. Jellenik** has joined Chemionics as general sales manager.

•

Allied Chemical's Barrett Division, 40 Rector St., New York 6, N. Y., has appointed four new managers in its reorganized technical department. They are **Joseph W. Donegan,** manager of technical service; **Richard K. Eberts,** manager of development research; **Robert L. Harris,** manager of laboratory research, and **Frank P. Maxwell,** manager of development engineering.

•

Oakwood Associates, with offices at Cocks Building, Box 186, Nanuet, N. Y., of which NACE Member **Seymour J. Fiebach** is president, has been appointed sales representative for East New York state and Connecticut of An-Cor Industrial Plastics, Inc.

•

An independent Anglo-Arabian consulting engineering partnership, Pencol Mid East, 67 Bella Vista Building, Rue de Phenicie, Beirut, Lebanon, has been registered under the direction of NACE Member **Kenneth A. Spencer,** who is also senior partner in both Spencer & Partners and Pencol Pipeline & Engineering Consultants, 19, Grosvenor Place, London, S. W. 1, England.

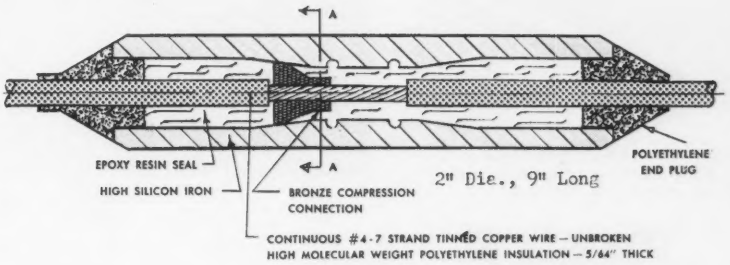
•

NACE Member **L. B. Rafsnider** has retired from The Ohio Bell Telephone Company, 750 Huron, Cleveland 15, Ohio.

•

NACE Member **Harold J. Read,** professor of physical metallurgy at Pennsylvania State University, University Park, Pa., has been presented the Henry Proctor Memorial Leadership Award by American Electroplaters' Society, Inc. **Abner Brenner,** chief of the Electrodeposition Section, National Bureau of Standards, Washington, D. C., has been awarded the society's Scientific Achievement Award.

High Silicon Iron Anode Assemblies on Continuous Conductor



Continuous conductor with 1100 lb. breaking strength is locked internally to each anode by bronze compression fitting, epoxy resin seal and polyethylene end plugs. Connection resistance is about 0.0006 ohms. Anodes tested withstood 120 psi. The high molecular weight, black polyethylene wire insulation resists chemical attack. High silicon iron anode installations can be designed for a life expectancy of 20 years. We space anodes to your design. This low-cost, easily installed system reduces interference problems.

We hold exclusively, U. S. Patent number 2,803,603 covering this type anode when used in duct lines. With low price and ideal assembly, may we serve you? Your inquiries are requested.

Rugged aerial and underground rectifiers furnished.

Anode Bulletins AF 535-B and Rectifier Dwgs AF 630, 646 & 654 furnished.

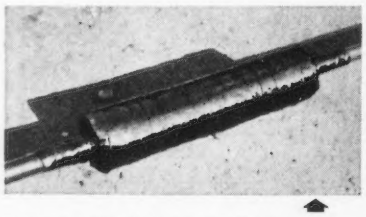
ARCH T. FLOWER CO. QUEEN ST. & IVY HILL RD PHILADELPHIA 18 PA.

TAPECOAT® PROTECTION.

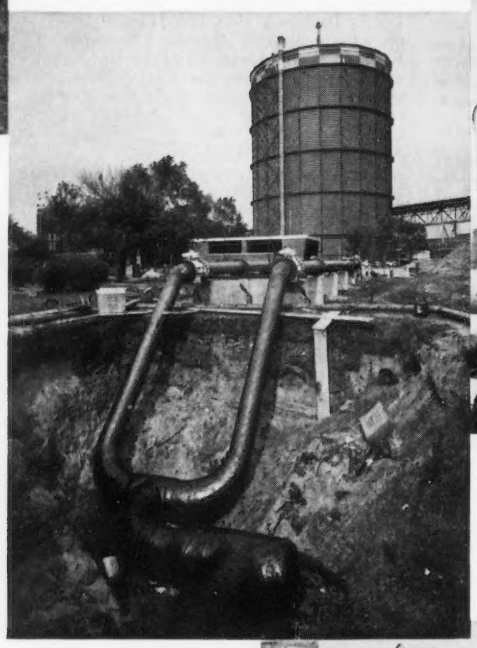
Works for You Anywhere!

NATURAL GAS lines at compressor and meter stations give years of maintenance-free service when protected by TAPECOAT, the coal tar coating in handy tape form.

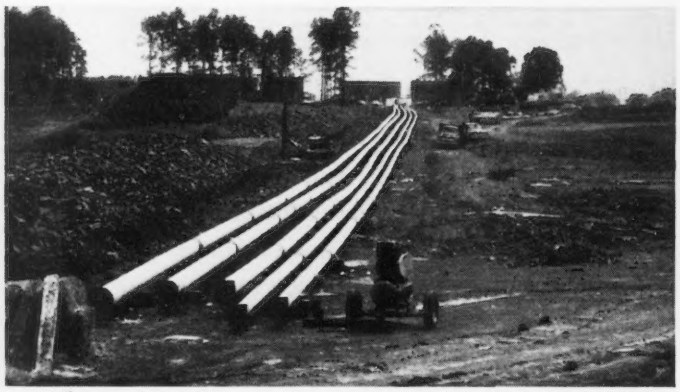
GAS DISTRIBUTION lines of large diameter can readily be protected with TAPECOAT to withstand the abrasive and corrosive climate in underground service.



CABLE AND CABLE SPLICES in communications service are effectively and economically protected by TAPECOAT.



Lines in **OFF-SHORE DRILLING** operations need joint protection equivalent to the mill-wrapping on the pipe. TAPECOAT is most economical because it gives lasting protection in underwater service.



AIRPORT FUEL LINES need the quality joint protection assured by TAPECOAT. It is easy to apply by spiral or "cigarette" wrapping depending on the size of the pipe. No training needed.

UNDERGROUND GAS STORAGE facilities can be "buried and forgotten" when protected by TAPECOAT. Note protection of tanks, pipe and pipe joints.

STEEL MILL water lines in this new plant are joint-protected with TAPECOAT. TAPECOAT can be used to advantage to protect any steel surface in underground service, as proved since 1941.

Lines buried in cinders in **RAILROAD YARDS** need the sure protection provided by TAPECOAT. There's a size for every purpose from 2" to 24" in width.

Write for full details today

The TAPECOAT *Company*

Originators of Coal Tar Coating in Tape Form

1529 Lyons Street, Evanston, Ill.

Manufactured and Distributed in Canada by
The Tapecoat Company of Canada, Ltd.,
25 Haas Road, Rexdale, Ontario.

T-1G-2 on Cement Linings Sets Scope

Task Group T-1G-2, Cement Linings, at its first meeting on July 6 in Tulsa established its scope: To prepare a summary of cement-lined pipe experience, a general specification and a recommended practice brochure and to encourage research and methods of evaluation.

Collecting information on the subject is the committee's present task. Very little published information is available, the committee reports. Manufacturers and users of cement-lined pipe are being canvassed for specifications and case histories with the request that information be furnished by September 1. This deadline was set so that the information can be sent to task group members for review before the next meeting September 28 in Dallas at the Ramada Inn, 6900 Cedar Springs Road.

R. S. Ladley of Phillips Petroleum Company, Bartlesville, Okla., is chairman.

T-1F to Review A.P.I. Paper on Sucker Rods

A cooperative arrangement between NACE and the American Petroleum Institute has been worked out whereby J. A. Caldwell, chairman of NACE T-1, Corrosion in Oil and Gas Well Equipment, will act as liaison officer between NACE and certain API committees, including the Committee on Standardization of Production Equipment.

First cooperative action is NACE assistance in revising API RP 11BR covering handling and carrying of sucker rods. R. L. McGlasson, chairman of NACE T-1F, Metallurgy of Oil Field Equipment, has accepted the assignment of working with the API task group in revising the report. He reports that preliminary drafts of theAPI paper will be submitted to several interested NACE task groups for review, after which a final draft will be presented to T-1F for approval. T-1F's approved draft will then be sent to API as NACE's recommendation.

Committee to Start Work On Metallizing Report

Task Group T-6B-20 on Metallizing will meet Tuesday, October 24, at the Shamrock Hilton, Houston, to begin work on a committee report. Tentatively, the group will meet in Normandy Room "A" at 1:30 pm. Anyone interested in joining this committee should contact Chairman Fred W. Gartner, Jr., F. W. Gartner Company, Box 1303, Houston, Texas. Vice Chairman is S. John Oechsle, Jr., Metalweld, Inc., 2617 Hunting Park Avenue, Philadelphia, Pa.

Eighty Attend Chicago Cooling Waters Meeting

Task Group T-5C-2, Corrosion by Cooling Waters (North Central Region), held its fourth meeting April 25 in Chicago. Approximately 80 people attended the all-day session. Chairman of this committee is Hayward Halford of Mobil Oil Company, South 20 Street, East St. Louis, Ill.

Four papers were presented. They are: Investigation of Cooling Tower Corrosion by J. R. DeMonbrun and J. R. Largey of Union Carbide Nuclear Company; Use of Non-Oxidizing Biocides in Cooling Water Systems by L. F. Probst of Betz Laboratories, Inc.; Effects of Suspended Solids in Cooling Waters by K. C. Channabasappa of Wright Chemical Corporation and Controlled Chemical Feeding by G. W. Schweitzer of Hagan Chemicals and Controls.

Progress reports were presented by the chairmen of the Cooling Water System Data Group, the Corrosion Rate Measurements Group and the Cooling Water Treatment Manual Group.

The meeting was concluded with demonstrations and a group discussion of two types of field units for determining water side corrosion and scaling on industrial cooling water circulating systems.

T-1G-1 Studies Plastic Coatings for Tubing

Task Group T-1G-1, Plastic Coatings for Tubular Goods, met in Houston May 23 to discuss high pressure and high temperature service, holidays, buying specifications, service experiences, new development, acid resistance at high temperatures, handling of coated pipe and evaluation of coated tubing in gas wells by iron content tests. Eleven members and eight guests attended.

At the meeting it was stressed that over-all remedies are impracticable because corrosion problems are solved separately and that all materials have limits in performance. In discussing baked-on plastic coatings, the group pointed out that manufacturers and users both suffer if a coating is inferior as the manufacturer protects his market only by providing the best coating possible.

Materials Deterioration in the Atmosphere

The Mechanism by Which Non-Ferrous Metals Corrode in the Atmosphere by P. M. Aziz and H. P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont.

Mechanisms of Atmospheric Corrosion of Ferrous Metals by C. P. Larrabee, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa.

Principles and Procedures Employed in the Design and Interpretation of Atmospheric Corrosion Tests by H. R. Copson, Research Laboratory, The International Nickel Co., Inc., Bayonne, N. J.

Deterioration of Materials in Polluted Atmospheres by J. E. Yocum, Bay Area Pollution Control District, San Francisco, Cal.

REPRINT PRICES. (Postpaid, except to addresses outside United States, Canada and Mexico, when additional 65 cents for book post registry must be added) Per copy, $2. Ten or more copies to one address, $1. For larger quantities write for quotation. National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

CONTROL OF PIPELINE CORROSION

This 61-page, 6 by 9-inch booklet is now in its fourth printing. Written by O. C. Mudd, formerly chief corrosion engineer for Shell Pipe Line Corp., it contains much of the basic information and common sense instruction needed to plan and execute cathodic protection systems on underground plant.

Per Copy, postpaid.....$1.25

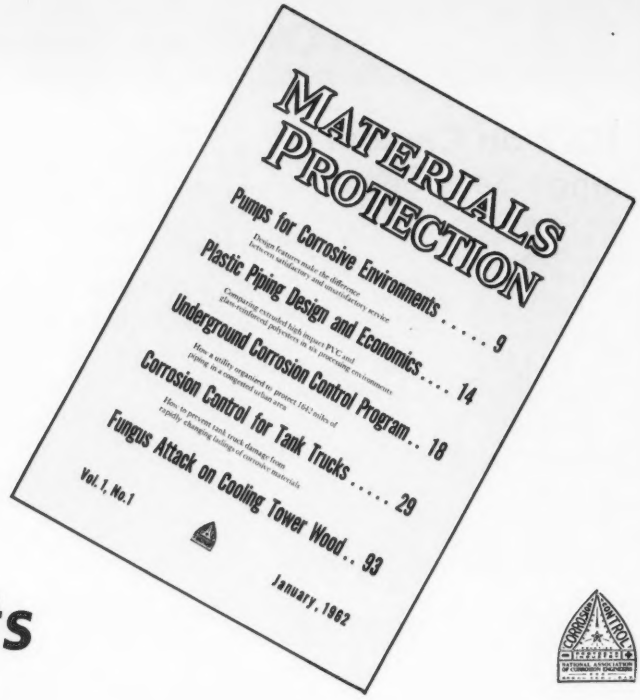
5 or more copies, each.....$1.00

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

First issue January, 1962


MATERIALS PROTECTION
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Vol. 1, No. 1
January, 1962

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Technical Program Announced for Okla. Short Course

This is the month of the Oklahoma Corrosion Control Short Course at the University of Oklahoma in Norman. To be held September 27-29, this well-rounded course is sponsored by the university's College of Engineering and Extension Division in cooperation with Central Oklahoma Section of NACE. Chairman is R. D. Daniels of the University of Oklahoma.

Registration will be conducted Wednesday, September 27, from 8 to 9 am in the main lobby of the Student Union Building on the Main Campus. Registration fee of $20 includes the banquet to be held at 7:30 pm Wednesday. Banquet speaker will be M. L. Powers, Director Business and Industrial Services, University of Oklahoma. His topic is The Ten Years Ahead.

The technical program is as follows:

Wednesday, September 27
Morning Session

How to Improve Your Corrosion Control Program Through Training by C. W. Gibson of Oklahoma Natural Gas Company.

Safety as Related to a Corrosion Control Program by W. V. Smith of Oklahoma Natural Gas Company.

Fundamentals of Corrosion

Chairman, M. L. Steffens, Oklahoma Natural Gas Company.

Corrosion in Action—A film of International Nickel Company.

Afternoon Session

Techniques of Corrosion Control

Chairman, John Knox, Halliburton Company.

Fundamentals of Corrosion Inhibitors by B. F. Davis, Jr., of Alox Corporation.

Fundamentals of Protective Coatings by G. R. Roberson of Standard Oil Company of Texas.

Materials for High Temperature Service by D. W. McDowell, Jr., of International Nickel Company.

Plastic Tubular Goods for Corrosion Resistant Applications by J. Barry of Carlon Products Corporation.

Cathodic Protection by O. W. Everett of Oklahoma Natural Gas Company.

Thursday, September 28
Morning Session

Techniques of Corrosion Control
(Continued)

Chairman, George W. Evans, Southwestern Bell Telephone Company.

Notes on Measurement and Evaluation of Various Modes of Corrosion Damage by E. E. Bennett of Phillips Petroleum Company.

Paint for Atmospheric Corrosion Protection by R. L. Gillogly of Continental Oil Company.

Water Treatment for Corrosion Control in Plants and Refineries by R. V. Whitty, Jr., of Hagan Chemicals and Controls Company.

Solving Cathodic Protection Interference Problems Cooperatively by T. J. Maitland of American Telephone and Telegraph Company.

Afternoon Session

Field Instrumentation and Demonstrations
(Demonstration Site, North Campus)

Chairman, Truel E. Adams, Arkansas-Louisiana Gas Corporation.

Cathodic Protection Instruments by J. R. Cowles of Agra Engineering Company.

Field Demonstrations:

Introduction by Truel E. Adams, Chairman.

Soil Resistivity Surveys by Elmer Curry, Cities Service Gas Company.

Pipe to Soil Potential Survey by T. L. Canfield, Cathodic Protection Service.

Surface Potentials Survey by T. L. Canfield.

Line Current Measurements by O. W. Everett, Oklahoma Natural Gas Company.

Cathodic Protection With Sacrificial Anodes, by O. W. Everett.

Cathodic Protection With Rectifier by O. W. Everett.

Galvanic Relations of Dissimilar Metals by C. L. Mercer, Southwestern Bell Telephone Company.

Evening Session

Corrosion Round Table

Chairman, F. B. Burns, Kerr-McGee Oil Industries.

Friday, September 29
Morning Session

Corrosion Problems in Petroleum Production

Chairman, D. H. Carpenter, Atlas Powder Company.

Corrosion From Reservoir to Pipeline by H. G. Byars of Atlantic Refining Company.

Metallurgical Problems Related to Significant Performance Properties of Production Equipment by R. L. McGlasson of Continental Oil Company.

Application of Down-Hole Corrosion Inhibitors by R. H. Poetker of Sunray Mid-Continent Oil Company.

Well Casing Cathodic Protection by J. Daly of Sunray Mid-Continent Oil Company.

Waldrip to Receive Spalding Award at Houston Conference

H. E. Waldrip, supervisor of the Production Unit, Technical Service Laboratory, Gulf Oil Company, Houston, has been named to receive the first J. C. Spalding, Jr., Memorial Award. The award was established by the South Central Region of the National Association of Corrosion Engineers in memory of the late J. C. Spalding, Jr., formerly a chairman and director representing the region. It is made in recognition of outstanding NACE activity by a NACE member of the South Central Region.

The award, in the form of a plaque, will be presented to Mr. Waldrip at the banquet to be held during the regional conference on the night of October 25 at Houston's Shamrock-Hilton Hotel. Dan H. Carpenter, of Atlas Powder Company, Oklahoma City, Okla., chairman of South Central Region, who heads the selection committee, will make the award.

Mr. Waldrip was selected from a number of NACE members suggested by sections in the South Central Region and members of the Selection Committee.

Mr. Waldrip holds NACE membership number 378 dated March 20, 1945. He has held every regional office and was a director representing South Central Region 1956-59. Besides being past chairman of Houston Section, he also has been active over the years in technical committees concerned with oil and gas well corrosion, most recently with T-1. He is past chairman of TP-1, predecessor of T-1.

H. E. WALDRIP

He also was active on the condensate well corrosion committee of the Natural Gasoline Association. He represented Houston Section on the Houston Engineers' Council.

He holds a BS in chemical engineering from South Dakota School of Mines (1930) and a professional degree in chemical engineering from the same school (1935). His principal interests in the corrosion field are problems associated with products pipe lines, condensate wells and subsurface corrosion in general.

South Central Region

Pipeline Symposium Added to Houston Program Oct. 23-26

A pipe line symposium has been added to the eight symposia already announced for the South Central Region Conference in Houston October 23-26 at the Shamrock Hilton.

This symposium will be held Wednesday morning, October 25. Chairman is A. T. Surber of Trunkline Gas Company, Houston, Texas. Co-Chairman is Paul D. Palmer of Columbia Gulf Transmission Company, Nashville, Tenn.

Scheduled for this symposium is a paper entitled New Resins, New Techniques and New Thoughts on Corrosion Resistant Coatings by Donald F. Koenecke of Enjay Laboratories, Linden, N. J.

Also set are a panel report and a panel discussion-open forum. The panel report, Reducing Friction Losses in Pipe Lines, is composed of the following papers:

Laboratories Studies of Internal Coatings by W. H. Jamison of Tennessee Gas Transmission Company, Houston, Texas.

Field Experience With Internal Coatings by C. H. Klohn of Tennessee Gas Transmission Company, Houston, Texas.

Internal Sandblasting of Pipe Lines in Place by A. W. McAnneny of Trunkline Gas Company, Houston, Texas.

Design and Application of Aluminum Pipe Lines by L. E. Pennington, D. V. Wilcox and R. S. Dalrymple of Reynolds Metals Company, Richmond, Va.

The panel discussion-open forum will cover Required Characteristics and Testing of Underground Coatings. Moderator is Russell Brannon of Humble Pipe Line Company, Houston, Texas. Panel members are Loyd B. Nelson of Shell Pipe Line Corporation, Houston, Texas; Donald F. Koenecke of Enjay Laboratories, Linden, N. J.; R. J. Emerson of El Paso Natural Gas, El Paso, Texas, and Jack P. Barrett of Pan American Petroleum Corporation, Tulsa, Okla.

Registration Starts 2 pm, Oct. 23, in Shamrock Lobby

Registration at the South Central Region Conference begins Monday, October 23, at 2 pm in the main lobby of the Shamrock Hilton, Houston. There is no pre-registration for this meeting.

During the conference the registration desk will be open as follows:

Monday, October 23	2 pm-5 pm
Tuesday, October 24	8 am-5 pm
Wednesday, October 25	8 am-5 pm
Thursday, October 26	8 am-Noon

Registration fee for NACE members will be $15, for non-members $17. Registration fee for lady guests, when accompanied by a full registration, is $7.50.

Lapel badges issued during registration will admit you to technical functions and the Fellowship Hour scheduled Tuesday, October 24, between 7 and 8 pm in the Shamrock's Emerald Room. Admittance to all events listed on the official program will be by registration only; there will be no extra charge for any event listed.

The conference Banquet will be held Wednesday, October 25, between 7:30 and 10:30 pm in the Emerald Room. Entertainment will be furnished by Buddy Brock and his orchestra.

Ladies Program Includes Boat Trip

A leisurely sightseeing boat trip on the Houston Ship Channel aboard the Port of Houston's "Sam Houston" to the San Jacinto Battleground and return is in store for the ladies attending the South Central Conference. At the battleground, where Sam Houston defeated Santa Ana and won Texas' independence, the ladies will be conducted on a tour of the towering San Jacinto Monument and treated to lunch at the San Jacinto Inn, famous for its delicious seafood feasts. This trip is scheduled Wednesday, Oct. 25.

The exotically decorated Satsuma Room on the first floor of the Shamrock Hilton will be the laides' headquarters Monday through Thursday between 9 am. and 4 pm.

Tuesday night the ladies are invited to the conference's Fellowship Hour between 7 and 8 pm in Shamrock's Emerald Room and Wednesday to the Banquet, also in the Emerald Room, starting at 7:30 pm, during which Buddy Brock and his orchestra will entertain.

Too, a tea is scheduled. The ladies' program is being handled by Mrs. T. E. Catlow and Mrs. D. R. Fincher.

34 Firms Planning Houston Exhibitions

Thirty-four companies so far are planning exhibits at the Fourth South Central Region Exhibition to be held at the Shamrock Hilton, Houston, with the Region Conference.

Eight more companies, over the 26 named in August CORROSION, Page 55, have reserved booths. The new exhibitors are:

Aluminum Company of America, Pittsburgh, Pa.

The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

Champion Chemicals, Inc., Odessa, Texas.

Crane Company, Chicago, Ill.

The Duriron Company, Inc., Dayton, Ohio.

Hanszen Plastics Company, Dallas, Texas.

Marwais Steel Company, Los Angeles, Cal.

Valvoline Oil Company, Division of Ashland Oil & Refining Company, Ashland, Ky.

Additional booths are available; these may be reserved by contacting R. W. Huff, Jr., NACE Exhibits Manager, 1061 M&M Building, Houston 2, Texas. Exhibition floor plan indicating numbered booths was published in May CORROSION, Page 54.

Houston Engineer to Speak at Shreveport

Floyd B. Thorn, a senior engineer with Cathodic Protection Service, Houston, Texas, will present a paper entitled Thermoelectric Generators for Cathodic Protection at Shreveport Section's October 3 meeting at the Shreveport Petroleum Club.

Mr. Thorn's paper will include:

Brief resume of the thermoelectric principle and a discussion of materials used in constructing these units.

Type units available to corrosion engineers for cathodic protection installations.

Engineering considerations for thermoelectric cathodic protection systems with details as to groundbed design and fuel supply.

Thorn

Operating experience of thermoelectric cathodic protection installation in Hugoton gas field in Western Kansas.

For the past eight years Thorn has been active in the development and installation of corrosion mitigation equipment for oil and gas production facilities. He was a Physics major at Baylor University.

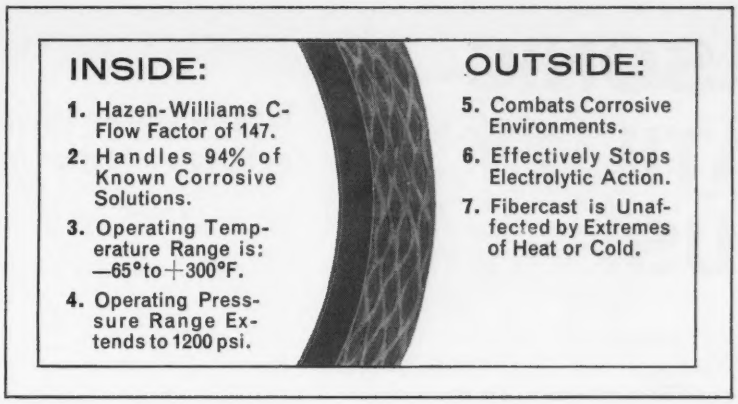
Plans for the evening also include a social period at 6 pm and dinner at 6:30.

Complete South Central Program in October

The complete technical program of the South Central Region Conference in Houston October 23-26 will be published in October CORROSION. Also all technical committee meetings scheduled will be listed.

Here's a brief review of the scheduled events: Registration starts Monday, October 23. Technical Committee meetings start Monday also. Conference symposia and the Exhibition begin Tuesday, October 24.

Plans are shaping up for all events: With the addition of the new pipe line symposium (see related story) nine are now scheduled. Also two more technical committees, T-6B-20 (Metallizing) and T-5A-3 (Alkali Environment), have announced their intention to meet during the conference, bringing the total to 21, to date 34 exhibitors have reserved booths, an interesting Ladies Program has been scheduled, the Banquet and Fellowship Hour have been set for the Emerald Room and the program is being printed. So now is the time to start making your plans to attend—and bring your wives.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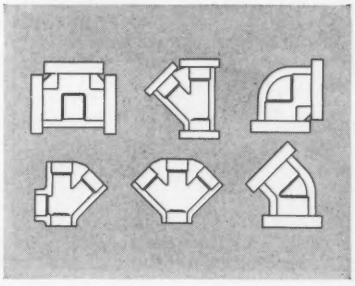
4. FIBERCAST provides superior resistance to high pressures. Its operating range extends to 1200 psi.
5. FIBERCAST has built-in inhibitors that combat the most highly corrosive environments and seals out contaminants.
6. FIBERCAST provides resistance to high tension forces. It is inert—stops electrochemical corrosion, forms an extremely durable dielectric shield.
7. FIBERCAST is unaffected by summer heat or winter cold; has superior resistance to severe atmospheres and weathering.



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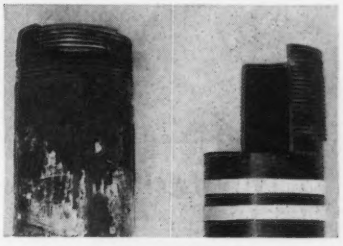

Fibercast Tubing (right) used to suspend a 1,200 lb. pump for 3 years in a salt water supply well. *There was no loss in strength.* The damaged plastic-coated steel nipple (left) was used in the same installation, failed after 3 months' service.

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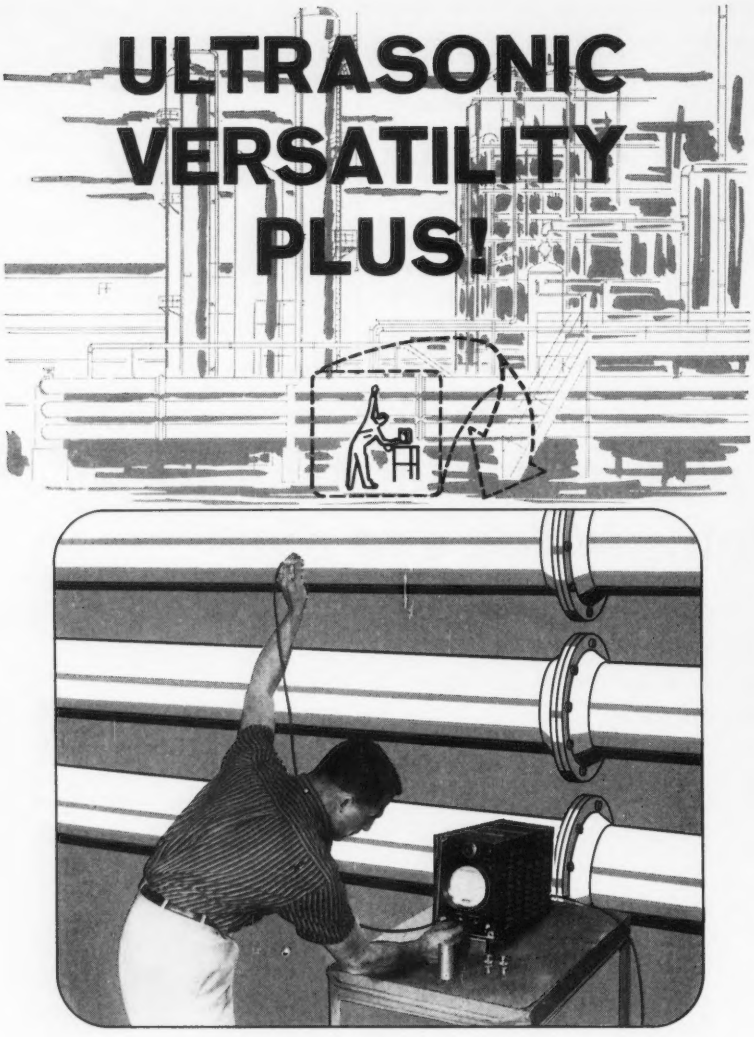

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South Central Region

Riggs Discusses Inhibitors at Houston Section Meeting

Young men coming into the corrosion control field face a challenge in the need for defining the reactions of organic molecules at surfaces. The need for a better understanding of the principles of inhibitor function was underlined by Olen L. Riggs, Jr., Continental Oil Co., Ponca City, Okla. in his opening remarks as featured technical speaker at Houston Section's August 8 meeting. More than 100 were present to hear him

discuss his company's work in the inhibitor field at the dinner meeting.

Mr. Riggs described some of the work he and his associates are doing in attempting to tailor organic inhibitors to fit specific corrosion conditions. This involves, he pointed out, an understanding of the present state of knowledge about the fundamental reactions involved in inhibitor action. With the principles well in mind, he asserted, the researcher then seeks to find molecular combinations which produce the desired reaction at the metal-environment interface.

D. R. Fincher to Head 1962 Houston Short Course

D. R. Fincher, Tidewater Oil Company, Houston has been named general chairman for the Houston Section 1962 corrosion control short course. O. A. Melvin, Carboline Co., section chairman also named the following to help conduct the course:

Marion E. Frank, Tennessee Gas Transmission Co.; Glenn R. Roberson, Standard Oil Company of Texas; Pierre R. Carpenter, Napko Corp.; Arthur C. Flory, Mavor-Kelly Company; E. C. Winegartner, Humble Oil and Refining Co.; Robert P. Naremore, Sunray Mid-Continent Oil Co. and Paul H. Mallette, Visco Products Co., Inc.

•

Houston Section will meet September 12 at Houston Engineering & Scientific Society. Robert J. Kuhn, consulting engineer, New Orleans, will speak on Do Casings Cause Pipeline Corrosion at Crossings?

(Continued on Page 63)

Northeast Region

33 Papers Scheduled at New York's Statler Hilton Oct. 30-Nov. 2

Thirty-three papers are scheduled to late for the Northeast Region Conference, four new papers having been added to the 29 published in August CORROSION, Page 62. A panel discussion on protective linings also has been set. The Statler Hilton Hotel, New York City, is headquarters for this meeting, at which eight symposia and two educational lectures will be held. The entire program schedule will appear in next month's CORROSION.

Listed under the symposium in which they will be presented are the additional papers:

Heat Exchangers Symposium

Some Practical Considerations for Controlling Corrosion in Salt Water Cooling Systems by Walter S. Janssen of American Oil Company, Texas City, Texas.

Protective Coatings Symposium

Recent Developments in Epoxy Resin Coatings by John Klorquist of Shell Chemical Company, Union Laboratories, Union, N. J.

Salt Water Conversion Symposium

Methods of Studying Corrosion by Saline Water by Norman D. Groves of Carpenter Steel Company, Reading, Pa.

Experience With Materials in Sea Water Service by Thomas P. May of The International Nickel Company, Inc., Wrightsville Beach, N. C.

●

Greater Boston Section held its short course at Wentworth Institute, Boston, June 20-22. Eighty attended.

South Central Region

(Continued From Page 62)

Alamo Section on August 15 heard Max Schlather of United Gas Pipe Line Company discuss economic aspects of corrosion control. Meeting is scheduled at DeWinne's Belgium Inn, 3119 West Commerce.

On July 11, C. W. Tipps of City Public Service Board, San Antonio, spoke on Electrical Components of Corrosion in Underground Structures.

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PRESIDENT'S NEWS LETTER

E. C. GRECO, President NACE

Dear Fellow Members:

In this, my first news letter to members of NACE, I wish to outline developments presently being put into effect by the officers of your association and to point out others now under consideration and study.

NACE, from a very small beginning in 1945, has grown to the foremost corrosion association in the world, recognized internationally as a leader in the field of corrosion technology. It has members in more than 70 countries and the journal CORROSION is read in almost every country of the world.

Your association conducts a large publication business, a very effective means of making available to members, subscribers and libraries all over the world the results of corrosion research and new developments in corrosion engineering. CORROSION, first published in 1945 and the official journal of the association, is internationally recognized as a leading journal of corrosion technology. In view of the diversified interests of CORROSION readers, a major change in format was made January, 1960, which moved the Technical Section to the back and the Technical Topics, NACE News, Technical Committee Activities, etc. to the front. This was done with the plan in mind that, in the future, CORROSION would be divided and the material published in two journals.

Beginning January, 1962, NACE will publish two journals, one called CORROSION and the other, MATERIALS PROTECTION. CORROSION will be a technical journal of the classical type devoted to articles presenting new scientific and engineering information. MATERIALS PROTECTION, an entirely new publication, will carry technical and engineering information of a general nature with emphasis on application, technical committee activities, NACE news, etc. The articles in MATERIALS PROTECTION will be cast in a language easily understood by anyone with an interest in and a concern for the control of corrosion and the deterioration of materials and equipment. Feature stories similar to the one on automobile corrosion which appeared in the Technical Topics Section of the February, 1961, CORROSION, will be prepared by staff members of the Houston Office and periodically published in MATERIALS PROTECTION.

A new bimonthly publication titled CORROSION ABSTRACTS containing abstracts of corrosion literature from hundreds of publications all over the world will be published beginning with 1962. These abstracts will be classified according to the familiar NACE classification system, each issue containing a comprehensive subject index.

To encourage an active corrosion research program, the NACE Board of Directors at a recent meeting in Houston, Texas, approved in principle a proposal of the Committee on Research. To emphasize the urgent need for NACE to assume the leadership in focusing the attention of the best available talents on the problems of our corporate members and industry in general, the board of directors approved funds which can apply toward the initial research project. It is the desire of the association's officers that NACE take a very active part in encouraging and promoting research in every area where corrosion has become a problem.

Your officers have recently concentrated their efforts on developing a program which when put into effect will greatly enhance the stature of the association and the corrosion engineer among technical societies and in the engineering profession. The program presently under development has several facets. These are described briefly in the following paragraphs.

The technical stature of the journal CORROSION will be enhanced by removing all nontechnical material, publishing only scientific and engineering papers. Already under way is a project designed to secure the best scientific and engineering papers on corrosion from every area of the world.

To improve the quality of the papers presented at the annual conferences, an Ad Hoc Committee on Technical Program Quality was appointed. The results of this committee's efforts will be apparent for the first time at the national conference in Kansas City, Missouri, March 17-23, 1962. The technical program at Kansas City will include a full day symposium where papers of a basic and fundamental nature will be presented by recognized corrosion scientists and engineers.

Another ad hoc committee was appointed by the board of directors to study and develop a publicity and public relations program for NACE. Publicity is a known means of achieving recognition by pointing out to the public the benefits derived from a given professional group. The committee has made a great deal of progress. The board of directors recently approved the employment of a professional public relations firm to assist in organizing a publicity program for one of the regional meetings. This initial trial will be used to test the plan and if the results are favorable the program will be applied in other regions.

Another ad hoc committee recently completed its assignment to define the qualifications an engineer must possess to be recognized as a qualified corrosion engineer. This became necessary when it was brought to the attention of the executive committee that state and county regulatory bodies were attempting to determine who should be recognized as a corrosion engineer qualified to certify plans and specifications where public welfare is a factor. Your officers felt that NACE could produce a more realistic and workable definition than groups with possibly only a vague knowledge of corrosion technology and engineering.

In relation to the definition of a professional corrosion engineer, a study, assigned to the Ad Hoc Committee on Membership Review and Grades of Membership, is under way. This committee will develop information and make recommendations to the executive committee on methods which can be used to determine who qualifies under the NACE definition as a corrosion engineer. Members who meet the requirements probably will be placed in a specific membership category (grade). However, it is contemplated that regardless of whatever changes may be adopted in membership designations these will not interfere with the ease with which anyone interested in corrosion can become a member of NACE. Also, it is contemplated that there shall be no difference in benefits received by either group, because both grades shall have the same membership privileges and benefits within the association.

Another reason for considering recognition of our professional members is that NACE has not been eligible for membership in the Joint Engineer's Council because the association does not recognize members with academic achievement.

Your comments and suggestions are invited and welcomed. Your continued support of NACE is appreciated by the officers and the Houston Office Staff.

With warm personal regards,

Edward C. Greco

President

NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1961

Oct. 4-6—Western Region Conference, Benson Hotel, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-26—South Central Region Conference and Exhibition, Shamrock-Hilton Hotel, Houston.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Nov. 27-Dec. 1—Southeast Region Conference and Florida General Conference Short Course, Key Biscayne Hotel, Miami, Fla.

Nov. 29-30—NACE Board of Directors Meeting, Key Biscayne Hotel, Miami, Fla.

1962

January 17-19—Canadian Region Eastern Division Conference, King Edward Hotel, Toronto, Ontario.

March 18—NACE Board of Directors Meeting, Muehlebach Hotel, Kansas City, Mo.

March 19-23—18th Annual Conference and 1962 Corrosion Show, Kansas City, Missouri, Municipal Auditorium.

March 23—NACE Board of Directors Meeting, Muehlebach Hotel, Kansas City, Mo.

October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N. Y.

October 9-11—North Central Region Conference.

October 11-12—Southeast Region Conference, Birmingham, Ala.

October 16-19—South Central Region Conference and Exhibition, Granada Hotel, San Antonio.

1963

March 18-22—19th Annual Conference and 1963 Corrosion Show, Convention Hall, Atlantic City, N. J.

October 14-17—South Central Region Conference, Oklahoma City, Okla.

October 22-24—Northeast Region Conference, Niagara Falls, N. Y.

1964

March 9-13—20th Annual Conference and 1964 Corrosion Show, Sherman Hotel, Chicago, Ill.

October 25-30—North Central Region Conference, Hotel Lemington, Minneapolis, Minn.

1965

March 15-20—21st Annual Conference and 1965 Corrosion Show, Chase-Park Plaza Hotel, St. Louis, Mo.

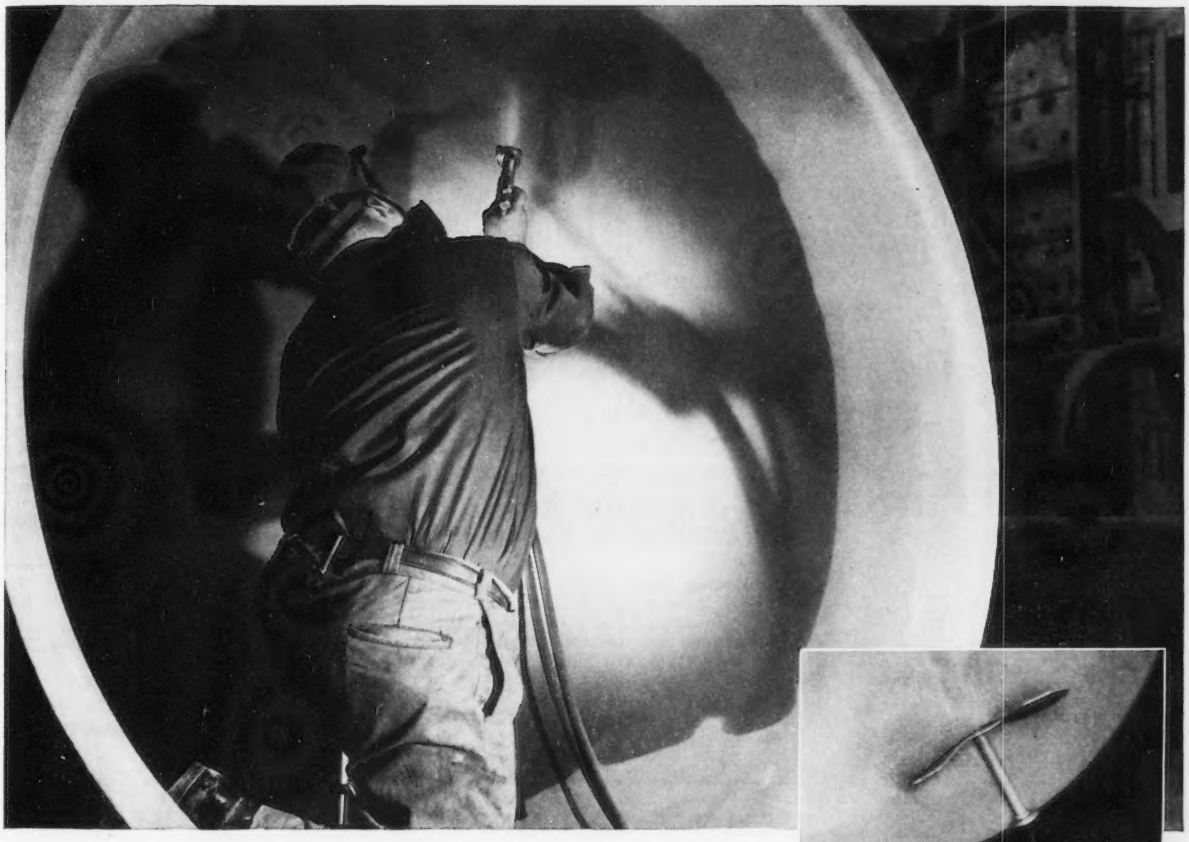
SHORT COURSES

1961

Sept. 20-22—Permian Basin Corrosion Tour, Odessa, Texas.

Sept. 27-29—8th Annual Central Oklahoma and University of Oklahoma Corrosion Control Short Course, Norman.

PENTON* at work: PFAUDLON 301



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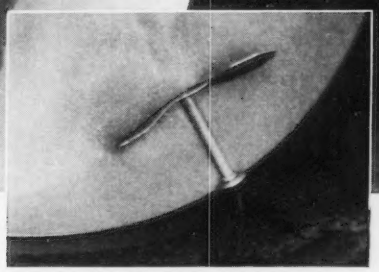

Pfaudlon 301 Stays On: Penton-coated agitator used to mix highly abrasive sandlike slurry in 3½% of 37% HCl in H_2O shows no visible corrosion after twelve months of steady production.

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North Central Region

Chicago Section Sets Program Schedule Thru December 1962

Chicago Section's Program Committee has arranged its program a year in advance.

September 19 will be ladies' night. Edward C. Greco, NACE president, will speak on What Has Happened to Education in Primary and Secondary Schools.

October 17, G. C. Wilson of the Institute of Gas Technology, Chicago, discusses Simple Concept of Potential—Key to Understanding of Reference Electrode Measurements and Cathodic Protection.

November 21 the section will hear J. W. McClellan of Corning Glass Works speak on Half a Century of Research in Glass.

January 16, J. I. Bergman of Armour Research Foundation, Chicago, will talk on Corrosion Inhibitors—Theory and Application.

February 20 a panel meeting will be held on Gas Distribution System Cathodic Protection. L. E. Nichols of Northern Illinois Gas Company will moderate the panel composed of E. F. Fowler, R. Nelson, T. Snedden and E. Paver, all with Northern Illinois Gas Company.

April 17, O. W. Siebert of Monsanto Chemical Company speaks on Special Purpose Panels for Testing Internal Barrier Coatings.

May 15, the final meeting, L. W. Gleekman of Wyandotte Chemicals Corporation discusses Titanium Successes and Failures in Chemical Corrosion.

In December, to avoid the Christmas rush of things, there will be no meeting. Also there will be no meeting in March because of conflict with the national meeting.

The men responsible for this well planned program are Program Chairman H. Kerst, E. S. Moorman, T. Snedden, Paul Puckorious, C. M. Crowe and J. Kothoff, Jr.

Canadian Region

Edmonton Section July 27 heard Murray A. Armstrong of Canadian Protective Coatings, Ltd., discuss cathodic protection engineering. On September 28 the section will meet at the Riviera Hotel. H. W. Lineker is the new Section Treasurer, replacing L. Sparks who resigned because of his leaving Edmonton.

St. Louis Program Has Several Changes

St. Louis is the place. The event: North Central Region's Annual Conference at the Chase Park Plaza Hotel October 9-11. Twenty-nine papers will be presented.

A few changes have been made to the program published in May CORROSION, Pages 50-51. These revisions are:

In the Non-Metallics Symposium, D. H. Hall and J. R. Little have changed their paper. Instead of Nucerite, a New High Temperature Corrosion Resistant Material, they will present High Temperature Corrosion Resistant Crystallized Glass Coatings for Industry.

In the Symposium on Protective Coatings—Organic, the title of W. E. Chandler and T. F. Stanley's paper Budgeting and Selling a Paint Program has been shortened to Selling a Paint Program.

In the Sheet Linings Symposium, one paper has been dropped, another added. Out is Fluorocarbon Linings by C. R. Payne; added is Lining of Pressure Absorption Towers to Combat Corrosion by H. Y. Allgood and Harry Nash, Jr., of Tennessee Valley Authority, Wilson Dam, Ala.

Regional Conference Program Information Published in Corrosion

North Central

May, Pages 50-51

July, Page 56

August, Page 62

Northeast

August, Page 62

South Central

June, Page 52

August, Pages 55-56

Southeast

May, Page 64

July, Page 58

August, Page 61

Western Region

June, Page 58

July, Page 47

August, Pages 58-59

NACE BUFFALO CONFERENCE PREPRINTS

A limited number of preprinted copies of the papers listed below, all from the NACE 1961 Conference in Buffalo, are available for sale at $1 per copy postpaid. Add 65¢ for book post registry to addresses outside the U.S., Canada and Mexico.

Paper No.	Title and Author
12	The Effect of Redox on Refinery Corrosion, by C. B. Hutchison and W. B. Hughes.
18	Painter Safety, by L. S. Hartman.
19	Commercial Hot-Dip Galvanizing of Fabricated Items Used in Construction of Industrial Projects, by L. R. Vickers.
23	Versamid-Epoxy Coatings—Corrosion Applications, by Harold Wittcoff, Don E. Floyd, David W. Glaser and Conald L. Andersen.
24	Protective Coatings for High Temperature Service, by Gatewood Norman.
29	A Method for Prevention of Hydrogen Embrittlement of Tantalum in Aqueous Media, by C. R. Bishop and Milton Stern.
32	The Casing Inspection Tool, An Instrument for the In Situ Detection of External Casing Corrosion in Oil Wells, by T. R. Schmidt.
34	A Basis for Design of Aluminum Alloys for High Temperature Water Service, by R. L. Dillon and H. C. Bowen.
54	The Electrochemical Approach to Cavitation Damage and Its Prevention, by H. S. Preiser and B. H. Tytell.
59	Corrosion of Superalloys at High Temperatures in the Presence of Contaminating Salts, by A. Moskowitz and L. Redmerski.
61	Iron Sulphate for Condenser Tube Control, by T. W. Bostwick.
65	Plastic Pipe Systems For Corrosion Resistance, by Allyn E. Webb and R. W. Johnson.
67	A New Design for Reinforced Plastic Tanks, by W. R. Wardrop and F. H. Humphrey.
70	Theory and Application of Deep Ground Beds, by J. F. Tatum.
74	Shot Peening for Protection Against Stress Corrosion Cracking, by Henry Suss.
78	Corrosion Measuring Sensors for Ships, by David Roller, Wilard R. Scott, Jr., Herman S. Preiser and Frank E. Cook.
81	Cavitation Erosion and Behavior of Materials, by J. Z. Lichtman, D. H. Kallas, C. K. Chatten and E. P. Cochran, Jr.
85	Gasketing For Corrosive Service, by Chas. M. Hobson, Jr.

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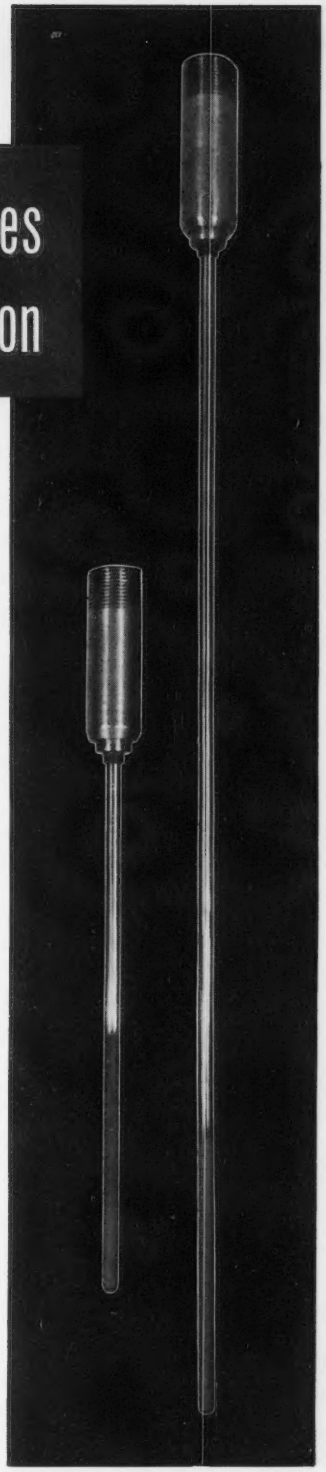

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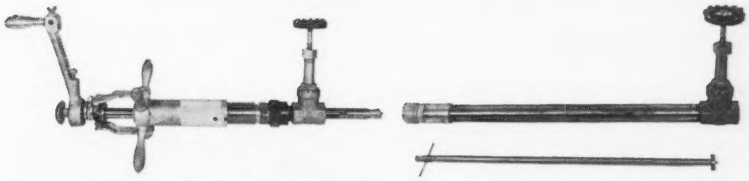

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Western Region

Portland's Mayor to Open Conference at Benson Hotel Oct. 4

Portland's mayor, Terry D. Schrunk, will open the Western Region's conference at the Benson Hotel Wednesday, October 4. Eight symposia will be held during this meeting running October 4-6. The complete technical program, including abstracts of papers, appears in August CORROSION, Pages 58 and 59.

Registration desk will be on the balcony of the Benson Hotel. This desk will be open at 8 am Wednesday and Thursday. Registration fee, which includes the Banquet, is $20. Pre-registrations, postmarked before September 27, are $15. Additional Banquet tickets are $6 each; the ladies are invited.

The Hospitality Hour will be held Thursday, October 5, between 6 and 7 pm in the Crystal Ballroom.

The Banquet starts 6:30 pm Friday, October 6. It also will be in the Crystal Ballroom.

Among the activities scheduled are daily breakfasts for symposia speakers. Also two Western Region Officers' luncheons will be held, one Wednesday, October 4, at 12:30 pm, the other Friday, October 6, at 12:30 pm.

Hotel accommodations are available at the Benson Hotel, where all conference meetings and activities will be held. Requests for reservations should be sent to John C. Moeller, Registration Chairman, WRD NACE Conference, Box 2426, Portland, Ore.

Two field trips are scheduled for Friday, October 6; both begin at 1:30 pm and transportation will be furnished for whichever tour you choose. Either should be very interesting. One group will travel to Bonneville Dam on the Columbia River, the other to Crown Zellerbach Corporation's paper processing plant at Camas, Wash.

Conference Chairman is Don D. McGregor of the U.S. Corps of Engineers, Portland, Technical Program Chairman is John Van Bladeren of Northwest Natural Gas Company, Portland. Pictures of conference officers and symposia chairmen were published in June Corrosion, Page 58.

•

Central Arizona Section had as its guest speaker June 27 W. H. Chapman of El Paso Natural Gas Company who presented highlights of El Paso Natural Gas Company's corrosion training program, which includes slides and discussion on corrosion causes and mitigation. Sixty-two attended this dinner meeting at the Hotel Westward Ho, Phoenix, Ariz.

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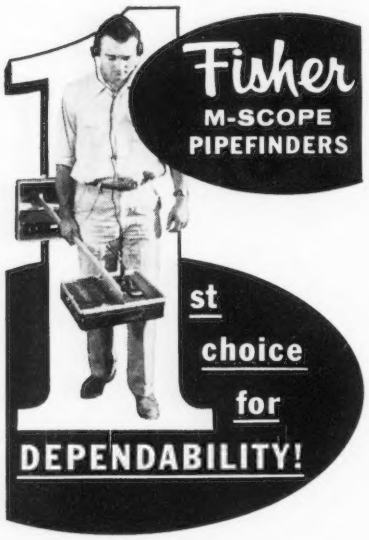
San Francisco Bay Area Section was treated to a tour of the Regal Pale Brewery June 6.



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Atomic Age Adds Corrosion Problems, NACE President Says

Although much has been accomplished in reducing the toll of corrosion during the past 20 years, the problem is far from a final solution. E. C. Greco, NACE president, talking to persons attending the June 6-8, 1961 Appalachian Underground Corrosion Short Course at Morgantown, W. Va., also said that the scope of the present corrosion problem is being expanded in modern industry. This comes about because of the environments implicit in atomic-age chemical processes, and the more strenuous demands being made on materials by changed engineering methods.

Ancient man was plagued by deterioration and rusting of his tools for labor and his weapons for war, thus threatening his existence, Greco said. Corrosion today means tremendous losses in money and natural resources, threatening future technological developments and resources upon which future generations must depend, he said.

The importance of corrosion, he added, is illustrated by the attendance at the First International Congress on Metallic Corrosion in London April 10-15 of this year when corrosion experts from 28 countries presented 67 papers. From countries outside the British Isles, Russia had the largest attendance with 43 members, the United States the next largest with 29, he said.

NACE Members in Many Lands

NACE, which provides a medium through which companies, engineers and technologists can communicate on the many facets of common corrosion problems, he pointed out, has grown in 16 years from 200 members to over 5000 and is the largest association devoted entirely to corrosion technology, its members living in almost every country. NACE encourages the training of young engineers in corrosion technology by promoting and in many cases conducting corrosion short courses at colleges and universities and by holding regional and national meetings where engineers inexperienced in corrosion control and those in research laboratories may attend symposia, lectures and technical committee meetings and discuss problems of mutual interest with leading corrosion experts, he said.

Support of Research Needed

Industry and government must continue to support corrosion research and the advice of the corrosion engineer must be considered in every area where metal products are manufactured and used, he emphasized.

His description of a corrosion engineer is a technically trained person who by experience has learned to apply pertinent fundamental principles borrowed from the various physical sciences to assail and prevent corrosion damage to metals in various forms on which man depends for technical developments and industrial growth.

The planned publication of CORROSION as two magazines, one retaining the name CORROSION and the other to be called MATERIALS PROTECTION, was announced by Greco in his talk. The new CORROSION will be devoted entirely to articles presenting new scientific and engineering information on corrosion technology. MATERIALS PROTECTION will contain general technical information of interest to corrosion engineers with emphasis on application, NACE news, related corrosion information and advertising.

Mr. Greco is a research associate in the Research Department of United Gas Corporation, Shreveport, La.

Southeast Region

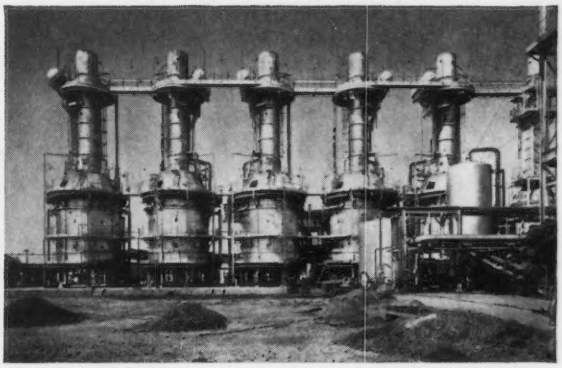
Greco to Be Keynote Speaker at Miami

NACE President E. C. Greco will give the opening address at the Southeast Region Conference at Miami's Key Biscayne Hotel. Registration for the conference to be held November 27-December 1 will be between 9 am and noon, Monday, November 27.

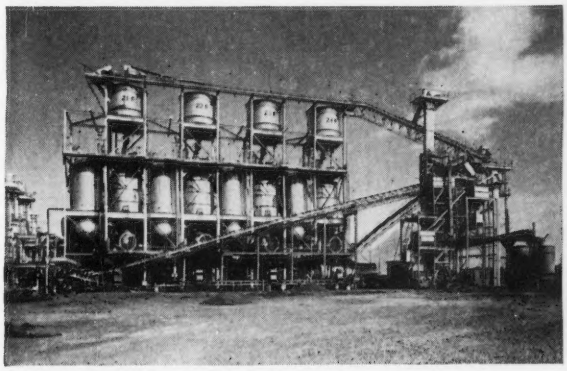
One new paper has been scheduled for the meeting in addition to the 20 published in August CORROSION, Page 61. It is Evaluation of Protective Coatings at Bradenton, Florida, Sewage Treatment Plant by Perry Cessna. The complete schedule, including dates the papers will be presented, will be published in October CORROSION along with information on the banquet, fellowship hour and other entertainment.

Registration fee will be $12. Banquet tickets are $5 each.

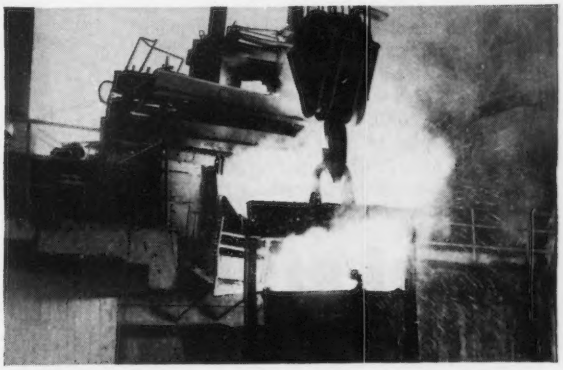
Step 1. Ore preparation. First step in Sponge Iron Process starts with Pihuamo and Durango ores being crushed and screened to ¼-1½ inch sizes. Ore is then poured into batch-type reactors. Some ores are first roasted to lower sulfur content.



Step 2. Natural gas is converted into hydrogen by catalytic steam reforming. After pre-heating and mixing with steam, the gas flows through heat-resistant Incoloy alloy tubes, which are heated to temperatures of 1400° to 1800°F.



Step 3. Direct Reduction. Process gas containing 85% hydrogen passes through reactors loaded with ore, removing 90% of the oxygen and 85% of any sulfur present. Reduced product averages 85% metallic iron, 15% iron oxide.



Step 4. Reduced ore to steel. Electric-arc furnaces melt the reduced ore to steel. The rimming and low-carbon steel ingots produced are exceptionally free of contaminants and have excellent qualities when converted to steel products.

Producing hydrogen for new iron ore reduction process...

Incoloy alloy tubing withstands furnace temperatures of 1400° to 1800° F

A new chemical process makes possible economical steel production by direct and continuous reduction of ore to sponge iron.

Developed by Hojalata y Lamina S. A., a leading Mexican steel producer, with engineering assistance from the M. W. Kellogg Co. of N. Y., the process involves the reduction of iron ore by hydrogen gas.

Steam-Methane Reforming is used to produce the all-important hydrogen. In the high temperature process, feed-gas—in vertically suspended tubes—is mixed with steam and heated at temperatures of 1400° to 1800°F. Operating pressures run as high as 125 psig.

To meet these demanding service conditions, extruded tubing of Incoloy* nickel-iron-chromium alloy was specified because of these specific advantages:

- Strength at elevated temperatures
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- Good weldability
- Freedom from sigma phase formation. In critical 1,100 to 1,600°F range, Incoloy alloy retains its ductility and impact strength.

If the selection of furnace tube materials is your responsibility, detailed information on the advantages of Incoloy alloy is yours with the helpful booklet, "Incoloy Extruded Tubing in the Petrochemical Industry." Just write to:

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SPECIFICATIONS

ACCURACY: ± .05% of reading or ± .5 mv., whichever is greater.

RANGES: 0—5.099 v. When used with PC-1, 0-500 v. and 0-1 amp.

SENSITIVITY: Infinite resistance at null. When used with PC-1, 2,000 Ω/v.

RESOLUTION: Continuous, 1 mv. divisions on slide wire.

BATTERY OPERATED: Does not require an external power source.

READOUT: Direct "in line."

SIZE: 9" x 4¼" x 1¾". **WT:** 3 lbs.

PRICE: Model PC, $325.00; Model PC-1 $125.00. F.O.B., New Rochelle, N. Y.

PocketPot*

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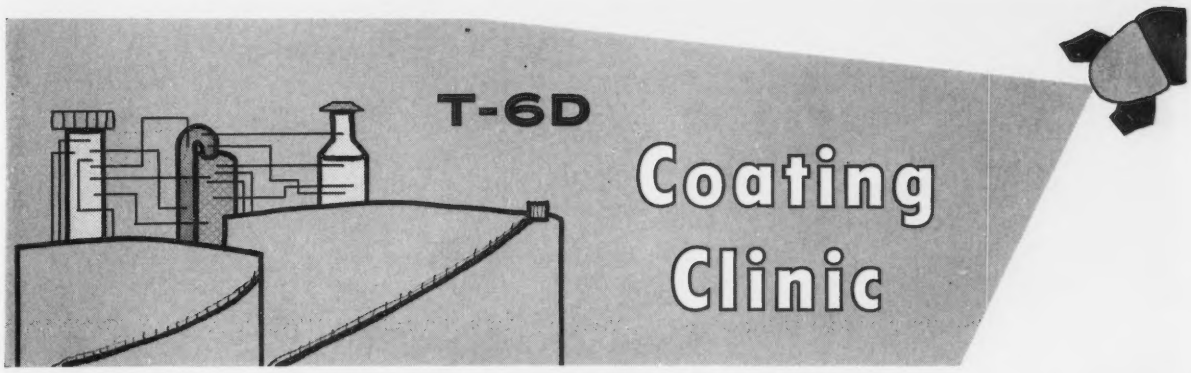

If you have a question or problem related to industrial paint applications, NACE Technical Unit Committee T-6D will forward it to qualified men in the industrial coating field for answers and suggested solution to problems. State your problem fully. Questions should be addressed to T-6D Coating Clinic, Corrosion Magazine, 1061 M & M Bldg., Houston 2, Texas.

Water Blasting

Describe conditions under which water blasting is the best method of surface preparation.

Answer: Under all conditions, water blasting should be considered as an aid to conventional methods of surface preparation, such as sandblasting. Water blasting is perhaps the best of all methods discovered to date for removing thick scale, thick oil or grease films, or thick coal tar or asphaltic type of coating **in advance of sandblasting or disc sanding** a surface prior to recoating.

An example of the economy this procedure permits may be instructive. It is not at all uncommon for a cost of $2 per square foot to be incurred when attempting to remove thick coal tar or asphaltic films, by sandblasting alone. Such films are somewhat resilient and display a marked tendency to rebound abrasives in the nature of rubber. Water blasting with pressures in the order of 3500 to 4500 psi will cut through such films quite rapidly and permit their removal at perhaps 20 to 25 percent of the cost of sandblasting alone.

Equipment Height Versus Coating Failure

Why do paint or coating films applied to the exterior of petroleum products storage tanks almost always display their first failure at the top two or three rings of the tanks?

Answer: From a straight environment point of view, the top two or three rings of petroleum storage tanks present a much less severe problem than the lower rings. This can be attributed to the fact that condensation almost always accumulates on the exterior shell below the liquid level and most tanks are maintained at no more than one-half full. The failure mentioned can be attributed to the fact that painting contractors almost always adjust the fluid and air pressure to match ground level conditions. Then, when the workmen and spray gun are elevated to the top two or three rings of a tank, a substantial reduction results in the fluid delivered to the spray gun while approximately the same amount of air is delivered as at ground level. The result is the deposition of dry or thin films relative to those deposited near the ground level.

There are two accepted solutions to this problem. The first consists of carrying the paint or material pot on the staging and keeping it at approximately the same level as the workman. The second solution consists of leaving the pot at ground level and applying one additional coat of material to the top two rings of the tank. The first of these two procedures is the recommended one.

Airless Spray

We have heard the claims about the economical advantages of airless spray application. Bring this to realistic figures produced by actual field experience. These advantages should reflect an applicator's viewpoint.

Answer: An industrial applicator contracted to sandblast and apply five coats of vinyl on a 140-foot diameter by 59-foot high floating roof tank. The application of the vinyl was difficult because this tank was located directly on the bay and the winds normally blow at 15 to 25 mph. Not only did the applicator experience very slow production, which was necessary to give a wet coat, but paint losses were incredible. The contractor's commitment was to furnish the material and apply a minimum of 5 mils. The contractor employed the use of an airless spray, which did three things to reduce his cost:

1. Reduced the number of coats from five to four.
2. Saved a substantial amount of material by reducing overspray losses.
3. Saved a minimum of 35 man-hours per coat because application was now possible at a rate comparable to spraying an alkyd.

The above is not intended to necessarily recommend the airless spray as a general method of application but does give an example where its use resulted in a distinct economic advantage to the applicator.

Heat Sensitive Paints

How long are heat sensitive paints effective? Is it obvious by their appearance when they are no longer capable of indicating a change in operating temperature.

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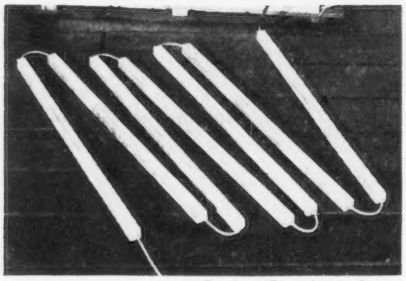
SECTION CALENDAR

September

6 Teche Section
7 West Kansas Section
8 Rocky Mountain Section
8 Birmingham Section
11 Central Oklahoma Section, Guest Speaker NACE Executive Secretary T. J. Hull
12 Montreal Section
12 San Francisco Bay Area Section, Application of Cathodic Protection by Paul O. Offerman of Standard Oil of California
12 Houston Section, Do Casings Cause Pipeline Corrosion at Crossings? by Robert J. Kuhn of New Orleans
19 Alamo Section
19 Chicago Section, Ladies Night, Guest Speaker NACE President E. C. Greco.
20 Wilmington Section, Chemical Cleaning by C. E. Fox of Dow Industrial Service
25 New Orleans Section
25 Philadelphia Governing Committee
28 Edmonton Section

October

3 Shreveport Section, Thermoelectric Generators for Cathodic Protection by Floyd B. Thorn
4 Teche Section
5 West Kansas Section
10 Montreal Section
11 Tidewater Section
17 Alamo Section
17 Chicago Section, Simple Concept of Potential—Key to Understanding of Reference Electrode Measurements and Cathodic Protection by G. C. Wilson of Institute of Gas Technology
27 Philadelphia Section, Fundamental of Corrosion by Robert Jelnick of Syracuse University.
30 New Orleans Section



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2. TESTING

2.3 Laboratory Methods and Tests

2.3.9, 2.4.2, 3.8.4, 6.3.10

Apparatus for Direct Observation of Low-Energy Electron-Diffraction Patterns. E. J. Scheibner, L. H. Germer and C. D. Hartman. Rev. Sci. Instruments, **31**, No. 2, 112-114 (1960).

Electron-diffraction patterns are made visible by exciting the diffracted electrons by a p.d. of 10^3 V before they strike a fluorescent screen. The technique is suitable for the study of metallic surfaces, particularly the effect of adsorbed gas layers. By observation of the complete pattern, it is possible that the dynamics of gas-adsorption phenomena may be followed. Examples are given for nickel. 24 references.—MA. 20900

2.3.6, 6.3.6

Copper Etching in Ferric Chloride. E. B. Saubestre. Ind. and Eng. Chem., **51**, No. 3, 288-290 (1959).

The mechanism of etching copper by a $FeCl_3$ solution is discussed. On the assumption that cooper is oxidized to Cu^+, Cu^{2+} is reduced to Cu^+, and Fe^{3+} to Fe^{2+} at the surface of the copper, and in the bulk of the solution. Cu^+ is oxidized to Cu^{2+}, and Fe^{2+} to Fe^{3+}, the composition of the $FeCl_3$ etch as a function of solution age is calculated. Results are given of the four ion concentrations with % theoretical exhaustion of the bath. Although Fe^{3+} plays the main role in copper etching in fresh solution, after the bath has become 50% exhausted, the etching reaction is essentially one of the Cu^{2+} reduction. The etching rate in a 3.75 M-$FeCl_3$ etch as a function of bath age is given. The hydrolysis of the ions present in establishing the pH of the solution and the point at which precipitation may form on the work being etched are considered. 21 references.—MA. 20907

2.3.9, 6.3.17

Quantitative Analysis by X-Rays of Uranium and Uranium Carbide Powders Oxidized at the Surface. (In French.) M. Pluchery. Centre d'Ètudes Nucléaires. Planseeber. Pulvermet., **8**, 14-21 (1960) April.

An X-ray absorption method for determining the oxide thickness on sperical powders is described. In the most general case the contribution of a particle to the total intensity of a Bragg reflection is: $I = K\phi(\Theta) \cdot H(\Theta)$. Θ is the Bragg angle, ϕ accounts for various factors (polarization, structure factor, etc.) and $H(\Theta)$ depends exclusively on the form of the particle. The ratio of the reflected intensity contributed by the uranium (or UC) core of the particle to the theoretical value is a function of the oxide thickness. It can be shown that this function, although the ratio of two discontinuous functions, can be interpolated into a continuous function. The oxide layer allows a similar treatment. From the comparison of the two interpolated functions the thickness of the oxide layer can be estimated under a very simple form. This allows extending the method to the case where the powder particles are of various sizes within a large range. The application of this method to standard samples of known oxide content yielded satisfactory results for thickness greater than 0.02 μ. Minute amounts of oxide are to be determined with an electron microscope method. Further experiments are being carried out for exploring the intermediate range. (auth.)—NSA. 20887

2.3.9, 3.4.3, 8.4.5

Photometric Procedures for the Analysis of Nuclear Reactor Corrosion Products. J. R. Ciaranello and K. E. Combs. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-JRC-2, December 16, 1959, 25 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C.

An evaluation of photometric procedures suitable for the determination of microgram amounts of iron, nickel, chromium, manganese and cobalt in nuclear reactor corrosion products is presented. Standard procedures were adapted for this purpose; in many cases, separations were necessary because of interferences. The analytical procedures were tested with synthetic samples of known composition and were found to give acceptable results. The methods were also applied to the analysis of corrosion products taken from nonradioactive systems. (auth.)—NSA. 20277

2.3.5, 2.4.2, 3.6.8

Measuring Equipment for Polarization Studies in Distilled Water. J. E. Draley, W. E. Ruther, F. E. DeBoer and C. A. Youngdahl. Argonne National Lab. J. Electrochem. Soc., **106**, No. 6, 490-494 (1959) June.

A technique of measuring polarization in distilled water is described. The Luggin capillary and the a-c-d-c bridge methods are discussed and judged inapplicable. The decay of polarization voltage (of aluminum) is shown to be relatively slow in this environment. A recording voltmeter and current interrupter suitable for making polarization measurements in low conductivity solu-

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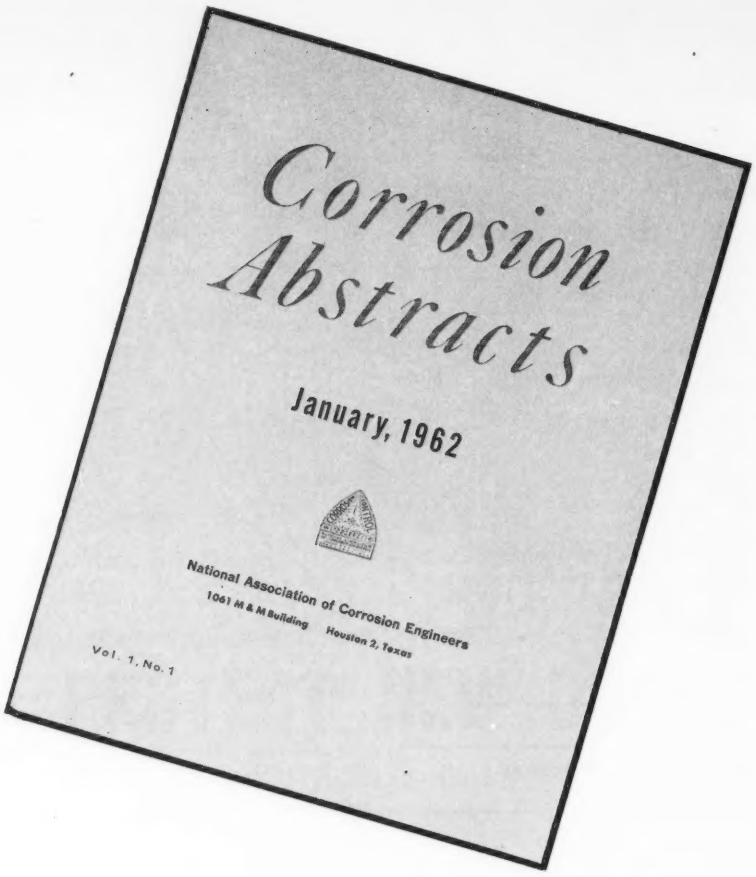
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106a

tions are described. The important design features of the electrolytic cell are discussed, and polarization data for aluminum in boiling water are given as an experimental example. 17818

2.3.9, 3.4.6

Analysis of Corrosive Gases by Mass Spectrometry. P. G. Bentley, J. R. Fothergill and A. N. Hamer. April 15, 1959, 19 pp. United Kingdom Atomic Energy Authority, Industrial Group, Capenhurst Works, Capenhurst, Ches., England, IGR-132(RD/CA).

Extent to which mass spectrometry can be usefully employed in the analysis of corrosive gas mixtures is discussed. Mixtures containing hydrogen fluoride and chlorine trifluoride are particularly considered. Details are given of the instrumental modifications and the operational procedures which are necessary if the gases are to be handled successfully. The problems of their adsorption and reaction at surfaces are discussed at some length. Limits of detection are normally about 1 percent of chlorine trifluoride, 0.1 percent of other corrosive gases and 0.01 percent of noncorrosive gases; these figures, depend on the nature of the other components in the mixture. (auth)—NSA. 19039

2.3.9, 3.8.4

Secondary Positive-Ion Emission from Metal Surfaces. Richard C. Bradley J. Applied Physics, **30,** No. 1, 1-8, (1959).

Bradley indicates the usefulness of mass-spectrometry of secondary ions as a tool for investigating surface phenomena, such as corrosion and catalysis. Surfaces of molybdenum, tantalum and platinum were bombarded by inert-gas ions of low energy (< 1000 eV) in high vacuum. Observations on the formation of platinum trioxide on a platinum surface and its desorption at high temperature are given. Another possible application, to the study of sputtering, is discussed, although the properties of the secondary ions are in general different from those of sputtered particles. The secondary-ions, characteristic of the base metal, comprise only a small fraction of the total sputtering yield, are principally singly charged and monat., have a low average energy (4-5 eV) and energy spread, and may result either from physical sputtering of the base metal or from the dissociation of surface compounds or both. 11 references.—MA. 19041

2.3.5, 3.6.4

Metals Coated with Films of Low Surface Energy as Reference Electrodes for the Measurements of Contact Potential Differences. K. Bewig and W. A. Zisman. Naval Research Lab., Washington, D. C. NRL-5383, August 3, 1959, 14 pp. Project NR 472-000.

Central problem in the measurement of the contact potentials of solid and liquid surfaces in gaseous atmospheres is the stability of the contact potential of the reference electrode to which the potential difference between the two is referred. Noble metals, such as gold or platinum, are usually employed as reference electrodes, but, in gaseous atmospheres, their contact potentials can change significantly because of vapor adsorption on the reference surfaces. This occurs even on aged metals, the effect of adsorbed water vapor being especially great. But a metal which has been coated with a low-energy film, such as Teflon or FEP Teflon resin, exhibits little change in the contact potential in a wide variety of polar and nonpolar vapors. This is demonstrated by the results of recent studies of metals in a nitrogen atmosphere in which the water vapor content was varied from 1 percent to as high as 91 percent R. H. Teflon-coated metal reference electrodes have proved to be remarkably stable under these conditions. (auth)—NSA. 19043

2.3.6, 6.4.2, 3.7.4

Microscopic Investigation of Corrosion Resistant Layers. (In German.) M. Hollo and F. Guba. Metalloberflache, **13,** 373-379 (1959) Dec.

Intercrystalline corrosion of aluminum-magnesium alloys. Geomorphology of electrolytically polished aluminum metal surfaces. Microstructure of nonmetallic coatings, oxide films, galvanic and lacquered coatings. 64 references. —RML. 19228

2.3.6, 3.7.4, 3.5.9

Research and Development of the Study of Brittle Fracture of Ship Plate Steel by Electron Microscopy. E. C. Haas. Material Lab., New York Naval Shipyard, Brooklyn. Jan. 7, 1958, 11 pp. Microfilms and photocopies available from Library of Congress, Photoduplication Service, Publications Board Project, Washington 25, D. C. (PB 143255).

An investigation was made of the applicability of electron microscopy in determining the relationship of the microstructure of ship plate steel to its brittle fracture transition temperature. Replication techniques were developed for imaging fractured surfaces. The electron micrographs of fractured surfaces failed to reveal physical features which were characteristic or correlatable with the transition temperature of the metal specimen, but the use of polished and etched specimens extended the usefulness of standard metallographic techniques at lower magnifications. Electron microscope studies were continued on mechanically polished and nital-etched specimens, and a large group of photographs were taken of areas considered characteristic of the specimens so that an experienced operator could match photographs with specimens. Selected electron photomicrographs are presented of several specimens of ship plate steel chosen to cover a wide range of temperature of transition from predominantly ductile to predominantly brittle fractures. The significant difference in the structures of these specimens is the spacing of the cementite lamellae, with the specimens of higher transition temperature showing a greater spacing of these lamellae. 4 references.—GRR. 19193

2.3.6, 3.8.4, 6.3.17

Refractive Index of Uranium Oxide Produced by Anodic Oxidation. A. E. Stebbens and L. L. Shreir. Nature, **183,** 1113-1114 (1959) April 18.

Interference colors observed during anodic oxidation of uranium in aqueous ammonia led to the investigation of an optical reflectivity method for studying film growth. Part of the oxide layer was dissolved in sulfuric acid leaving an oxide step which, when measured, gave a refractive index of $\mu = 1.93$. The technique was extended so that even if the metal is soluble in the acid, an oxide wedge can be formed which exhibits interference fringes which can be studied. This method yielded a value of $\mu = 1.95$. —NSA. 18565

2.3.2, 5.3.4

Testing Plating Durability. The Copper-Accelerated Acetic Acid Test. George L. Sukes. Metal Finishing, **57,** 59-65 (1959) December.

Corrosion of plated parts in service and in various salt sprays including Cu, Ni, Zn, Cd and Cr plated individually or in combination on steel or Zn-base die castings. Conditions for the Cass test duplicate in 30 hr. of exposure the equivalent of one year's service. 8 references.—RML. 19520

2.3.2, 2.5

German Standardization Practice with Accelerated Corrosion Tests. Pt. I. B. M. Pearson. Corrosion Prevention and Control, **6,** No. 1, 50-51, 54 (1959).

Fifteen different laboratories carried out standard accelerated tests to compare results with one another and with actual corrosion. Descriptions are given of the salt-spray test with different methods of producing the spray, humidity cabinets, and a cyclic moist-SO_2 test. —MA. 19366

2.3.2, 2.5, 5.4.5

Accelerated Weathering Test. H. Ladeburg. Blech, **7,** 184-188 (1960) April.

Accelerated tests of various kinds are used extensively for paint but are also employed for corrosion testing with a wide variety of other materials. The conditions for testing are laid down in a large number of standards intended for different purposes. Some American, French and German standards are compared. Standards differ in the temperature used, duration of the selected effect or effects (e.g., alternation of wet and dry conditions or permanently wetcondition), nature of the corrosion medium, etc. The most useful feature of the information supplied are 11 diagrams showing graphically temperature and relative humidity as a function of time to show how these factors should vary during the various cycles of these tests. —RPI. 21456

2.3.9

To Check the "Super" in Superalloys . . . This Test for Oxidation Resistance. Rod Simenz. Boeing Airplane Co. Product Eng., **30,** No. 17, 48-50 (1959) April 27.

New technique peers beneath surface to understand and gage damage done by oxidation. It measures oxidation effects in a flat metal panel by photographing cross-section after exposure at test time and temperature. Two-step procedure is described. When total af-

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fected depth is plotted against exposure temperature for a given time, curves can quickly compare oxidation resistance of a number of alloys. Photomicrographs compare 4 superalloys (Hastelloy X, D-979, Unitemp 212, Haynes 25) given same cyclic heating test at 2200 F. Accompanying table of 7 superalloys (Hastelloy X, R-235, Rene 41, Inconel X, D-979, Haynes 25, Unitemp 212) tested by metallographic technique gives clues to their relative oxidation performance. Source, alloy base, principal alloying elements and rank at 2200 F (1-hr exposure) are listed. Curves compare oxidation resistance and tensile strength. Limitations of method are considered; it will, however, give useful preliminary information and let designer screen many materials at outset of a new problem.—INCO. 18669

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 8.9.5

Cathodic Protection. Review of Marine Applications. P. H. Hopwood. Corrosion Technology, **7**, No. 4, 118-120 (1960) April.

Review of experience in applying cathodic protection to tankers. First British application of cathodic protection to cargo-ballast tanks was in 1952 using magnesium anodes. Its success lead to protection of immersed hull areas and water ballast spaces in all types of vessels. Anode safety, galvanic external protection, and marine fouling are considered. Use of impressed current on depot ship during underwater oil exploration is cited; graphite anodes mounted on frames were hung overboard and underwater hull left unpainted. Impressed current system for ships in operation was made possible by production of platinized titanium anodes of rectangular plate section. —INCO. 20338

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5.2.1, 8.9.3

Good Line Coatings Cut Cathodic Protection Costs. H. M. McCamish. Petroleum Engineer, **1960**, D24-D26, March.

A review of cathodic protection techniques and coating specifications on pipelines. Results of tests carried out on an X-42 pipe, 2.93 miles long, 6 in. in diameter, which had been coated with fully plasticized enamel. Testing by means of rectifier and ground bed system, using a magnesium anode. Figures for soil resistivity, current density, drainage, voltage and anode life. Installation costs and handling methods. —RML. 20062

5.2.1

Internal Cathodic Protection. Pt. 5. C. Plumpton and C. Wilson. Corrosion Prevention and Control, **6**, 34-40 (1959) Dec.

Problems involving closed rectangular boxes. Mathematical analysis required for solution of the problems involving long straight-line anodes placed inside rectangular tanks and parallel to the sides of these tanks (or within cylindrical tanks and parallel to the generators of these tanks). —RML. 20014

5.2.1, 3.8.2

Distribution of Potential and Current with Cathodic Corrosion Protection. (In German.) Carl Wagner, Werkstoffe u. Korrosion, **11**, No. 11 (suppl.), 673-680 (1960) Nov.

The distribution of the potential and of the current in local cells and with cathodic corrosion protection can be calculated from the differential equation for the electric field in an electrolyte solution. The relevant limit conditions are formulated in a general way. In the case of sacrificial anodes and external current, solutions for simple limit conditions are put forward, and the general conclusions are discussed. Where it is necessary to protect major objects, it appears desirable to use external current which is automatically regulated in such a way that the local electrode potential measured by a probe at the most exposed point, is equal to the potential of a just about negligible metal dissolution, but not much more negative, so that cathodic hydrogen development is minimized, especially at points situated next to the anode. 21184

5.2.2, 8.9.5, 1.2.2

Cathodic Protection of an Active Navy Tugboat with Zinc Anodes-42 Months' Service Test. H. S. Preiser & B. H. Tytell. J. Am. Soc. Naval Engrs., **71**, 253-256 (1959) May.

Service tests over a 41-month period on the bottom of an active navy tugboat lead to the conclusion that zinc anodes (Spec. MIL-A-18001) containing less than 0.0014% iron are suitable for the cathodic protection of active and possibly inactive ships berthed at sea water sites. Despite the formation of soft porous surface corrosion products, these zinc anodes continue to provide protective current output as long as there is zinc metal remaining. The zinc anode cathodic protection system is self regulating and low bulk, thus minimizes turbulence. With its efficiency of 95%, zinc is one of the most economical anode materials for active ships requiring moderate amounts of protective current; it loses little weight through self corrosion regardless of the current demand. The cost of installation of renewal of zinc anodes is comparatively low; cost of zinc per ampere-year is estimated at $5.20, comparing to $7.20 for aluminum anodes containing 5% zinc and $6.80 for magnesium anodes. Self corrosion occurring during a period of low current output increases cost much less for zinc than for aluminum and magnesium.—PDA. 20859

5.2.2

Processes Observed in the Use of Zinc as a Sacrificial Anode. (In German.) E. Eberius and H. Bones. Metall, **14**, 785-789 (1960) August.

A zinc plate is electrically connected to a plate of shipbuilding steel and both are immersed in an aerated and circulated NaCl solution, water potentials for various sections of the plate are measured. Effects of Zn-steel surface area ratio, distance between the plates, partial painting of the steel and rotating of the plates. Acidity changes of the electrolyte. 7 references.—RML. 21305

5.2.3, 8.4.2

Thermoelectric Cathodic Protection. Earl Tornquist. American Gas Journal, **1960**, 20-21, March.

A 10-watt thermo-electric generator unit using gas for fuel is used to impress, a low-voltage direct current on buried gas mains to cathodically protect them against corrosion; 27 high efficiency thermocouples convert heat into electric power. Hot junction temperature must be kept in 900-1000 F range. —RML. 21076

5.2.3, 8.9.5, 6.2.3, 3.5.8

Effect of Cathodic Protection on the Corrosion Fatigue of Mild Steel. (In Japanese.) Hideo Kada and Kazuo Takemura. Corrosion Engineering, **8**, No. 6, 243-245 (1959) June.

Propeller shaft of a ship is normally electrically insulated from the ship's hull while the ship is moving. Under such condition the galvanic anode on the ship's hull cannot prevent galvanic corrosion of the propeller shaft. Some torsional fatigue tests were made on mild steel pieces immersed in salt water and protected cathodically with impressed currents; corrosion fatigue strength was found to increase with amount of protection given. The current density needed for complete prevention of corrosion for steel plate statically immersed in salt water is commonly agreed to be of 150 mA/m²; our results with torsional fatigue tests showed that 700 ~ 800 mA/m² were needed. Consequently propeller's corrosion can be prevented with application of cathodic protection with current density a little above 800 mA/m².—JSPS. 19847

5.2.4

Formulae for Approximate Estimation of Resistance to Remote Earth. 1st Rept. (In Japanese.) M. Hanada and M. Toyobe. Corrosion Engineering, **8**, No. 6, 245-249 (1959) June.

Estimation of resistance to remote earth is one of the most troublesome and uncertain problems in the design of ca-

thodic protection. Author intended to get the practical formulae by experiments, and found that the resistance to remote earth (ohm) can be expressed with the equation $R = (\rho/L) \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_4 \cdot f_5 \cdot f_6$ as multiples of several functions. Where ρ is the resistivity in ohm cm and L the length of the electrode in cm.—JSPS. 19849

5.2.2, 8.9.3

Various Designs of Installations for Electrochemical Corrosion Protection of Underground Pipelines. (In Russian.) V. V. Krasnoyarskii. Stroitel. Truboprovodov, **4,** No. 9, 11-14 (1959) Sept.

Three magnesium alloys used as sacrificial anodes for the protection of pipelines in the U.S.S.R., differ with respect to aluminum and zinc content. Their electrochemical characteristics are adversely affected by nickel, copper, and iron impurities. For a given constant current, the zone in which a cathodic protection station is effective does not significantly change on removal of the anode ground connection if such removal does not cause the potential at the drainage point to fall below the value of the protective potential. 19787

5.2.1, 8.9.3

Installation and Operation of Protection Units on the Saratov-Moscow Gas Pipeline. (In Russian.) V. V. Krasnoyarskii and E. A. Nikitenko. Gazovaya Prom., **4,** No. 9, 42-46 (1959) Sept.

After preliminary trials with 219 cathodic protection points along 10 km. of the Saratov-Moscow gas pipeline in 1952, 5219 additional units were installed over a distance of 370 km., or 43.8% of the total length of the line. The protective current of 20-50 ma., selected to provide a safety factor of two, proved too high after replacement of defective insulation on numerous sections of the line. The spacing ranged from 46.5 m. to 135 m. The total cost of the cathodic protection for an average spacing of 69 m. is 0.165% of the cost of the pipeline, or 1/38 of the annual depreciation allowance. 19789

5.2.1, 8.9.5, 7.3

Basic Requirements of Corrosion Control—Cathodic Protection. W. O. Clark. Corrosion Technology, **7,** No. 4, 114-117 (1960) April.

Discusses experience in U. S. Navy with various cathodic protection systems. Attempt to increase protection for rudders, propellers and shafting by concentrating short-circuited zinc anodes in stern area was unsuccessful. Improvements were realized by use of controlled magnesium anode system, although over- and under-polarization still occurred. On small ships, satisfactory systems were achieved by remotely grounding magnesium anode through manually controlled resistance. On U. S. Navy ship-installations, propellers, after 3-year period, still show original polish marks; this is in direct contradition to accepted theory of cavitation erosion of propellers. It has been determined that wood-hulled ships require same method of protection as steel ships. Use of impressed-current systems for fixed structures and inactive ships is covered and early failures are discussed. Sabins D. Dohrmann Inc. has developed several types of anodes and stepless control systems. Ships requiring high speeds need systems using special Pb-Pt anode which is flush mounted. Ships operating at moderate speeds, tanks and fixed structures may use zinc anodes. Cathanode impressed-current type system used zinc anodes and has power requirement of 1/10 that required for Pb-Pt type. Graph shows polarization level adjacent to anode in both Pb-Pt and Zn anode systems.—INCO. 20290

5.2.1, 8.9.3, 5.11

Design for Pipelines. Pt. 1. D. Spector. Corrosion Technology, **7,** 103-106 (1960) April.

Plans for dual cathodic protection installation of 6 and 16-in. pipeline. Impressed current system with rectifiers, magnesium anodes and ribbons protects fuel line that crosses irrigation networks, water mains, power cables and telephone cables.—RML. 19982

5.2.1, 5.4.10

Cathodic Protection and Coatings for Buried and Submerged Steel and Reinforced Concrete. (In French.) Bernard Heuze. Nature, **1958,** 472-479, Dec.

Coordination of cathodic protection and coatings; dangers of improper use of coating materials, incompatibility with metals in certain cases; use of coatings to limit interactions between a cathodic protective device and a non-protected installation in vicinity. Examples of protection of pipelines, floating docks, heating plants.—RML. 19816

5.2.1, 4.5.1

Cathodic Protection Applications at the Hanford Works. C. S. Bucholz. General Electric Co. Applications and Ind. (Am. Inst. of Electrical Engrs), No. 46, 394-399 (1960) Jan.

Existing or proposed cathodic protection (CP) installations at Hanford are described. The soil has a very high resistivity, from 5 to 100 kohm-cm. Most of the original cast-iron, galvanized-steel, and carbon-steel underground piping installed in 1943 and 1944 is in good condition, but direct burial of unprotected stainless steel pipe has not been successful. The stainless steel lines now are encased in concrete ducts or are covered with a bituminous mastic to deter corrosive action. The anodes for the CP systems are made primarily of rails. Rectifiers rated at 24 v output are used to supply a current of 1 ma and a potential of —0.06 v. CP methods are presented for water storage tanks, reactor containment vessels, and reactor cooling water retention basins.—NSA. 20268

5.2.1, 3.2.2, 6.2.2, 7.3

Further Experiments on the Prevention of Pitting Attack on Cast Iron Propellers by Cathodic Protection. R. I. Higgins and H. H. Collins. British Cast Iron Research Assoc. Rept. No. 528. J. British Cast Iron Research Assoc., **8,** No. 1, 39-66 (1960) Jan.

Effect on Mg anode life and current output of 2 sizes of shroud (half and full) was investigated. It was concluded that when operating in sea water, half-shrouded anode will last 1.3 years and will have initial current output of 3.3 amp. which falls to 1.3 amp. as Mg is consumed, while fully-shrouded anode will last 2.2 years and will have initial current output of 2.1 amp. decreasing to 1 amp. Although service tests which have been carried out do not enable strict comparison to be made of effectiveness of fully- and half-shrouded anodes, greatest reductions in pitting attack were observed when using half-shrouded anode, but it was not possible to eliminate pitting attack completely. It is impractical to increase size of anode, but bare area of propeller can be reduced appreciably by heavy-duty coating. Alternative method of supplying current from Mg anode fixed to hull instead of propeller is described. In principle this system should deliver greater current output than half-shrouded anode, but in practice, metallic resistances which would normally be considered very low have substantial effect on output of galvanic current. Selective cathodic protection of propeller is only possible when contact resistance between propeller shaft and hull is high enough. More than 90 percent of current will flow to propeller when shaft-hull contact resistance is >0.3 ohms. There is some evidence that this contact resistance is dependent on type of bulkhead and sterntube glands and gland packing. Tables, graphs, diagrams.—INCO. 19844

5.3 Metallic Coatings

5.3.4

Methods of Obtaining Improved Outdoor Corrosion Resistance with Nickel Plus Chromium Plate. H. Brown and D. R. Millage. Trans. Inst. Metal Finishing, **37,** Pt. 1, 21-27 (1960) Spring.

Outdoor corrosion resistance of chromium plated, polished Watts nickel is compared with that of bright nickel. Following systems of composite plates are reviewed: bright, crack-free chromium (0.03-0.08 mil thick) on nickel or copper + nickel plate; the usual 0.01 mil Cr on dual or duplex nickel plate consisting predominantly of a thin overlay of bright nickel on a deposit of soft, semi-bright, sulfur-free nickel; dual or duplex microscopically cracked bright chromium plate (0.03-0.1 mil thick) deposited on nickel or copper + nickel; and chromium + nickel + chromium composite deposits.—INCO. 20126

5.3.4

Electrodeposition of Copper, Nickel and Bi-Metal Sheets. E. Carrington. Electroplating and Metal Finishing, **13,** Nos. 3, 4; 80-84; 126-129, 143 (1960) March, April.

Describes experiences in factory-scale production of thin metal sheets by electrodeposition. Copper and nickel sheets 12′ x 4′ and 9.5 mil thick were produced from $CuSO_4/H_2SO_4$ and from $NiSO_4/H_3BO_4/KCl$ solutions respectively on to revolving stainless steel mandrels. Sheets were of even thickness, had smooth

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non-glossy surface, were highly ductile and cheaper than rolled sheets of comparable thickness. Corrosive nature of hot solutions made filtration a problem and resulted in attack on immersion heaters. Brushing copper deposits as it was formed with glass brushes or agate blocks refined grain structure. Nickel deposition was comparatively free from trouble but spots or nodules were encountered in copper plating. Bimetal sheet consisting of 23 mil of Cu + 5 mil of nickel was produced for pressing into saucepans in one operation without heat treatment. Depositing copper onto nickel was easier than depositing nickel onto copper. Operating conditions, chemical and electrical control of plating process and recovery of copper are described.—INCO. 20270

5.3.4

Corrosion Protective Characteristics of Decorative Chromium Plate. W. H. Safranek, H. R. Miller and C. L. Faust. Plating, **47**, 513-519 (1960) May.

From a study of chromium plate quality as related to plating conditions, ranges were established for depositing crackfree and nearly porefree chromium, which inhibited corrosion in the nickel plate on which the chromium was deposited. The crackfree and porefree chromium also inhibited basis-metal corrosion in copper- and nickel-plated zinc die castings.—BTR. 20036

5.3.4

Electrolytic Deposition of Ferro-Chromium Alloys from Complex Chromium-III-Sulphate Solutions. (In German.) W. Machu and M. F. M. El-Ghandour. National Research Center, Cairo-Dokki, Egypt, UAR. Werkstoffe u. Korrosion, **11**, No. 5, 274-283 (1960) May.

Knowledge of the properties of Cr-III-sulfate and Fe-III-sulfate baths containing urea and NH_4SO_4, has made possible closer studies of the deposition of the ferro-Cr alloys. During deposition of the alloy, both metals are subjected to considerable polarization so that the Fe separation, in particular, is made difficult. This is ascribed to the presence, on the cathode surface, of a diaphragm consisting of chromium hydroxide.

Under the most favorable conditions encountered, the alloy contains some 18-20% Cr, the remainder being Fe; it thus corresponds to the composition of a stainless steel. The current yield amounts to 30% at most, and the occurrence of cracks in the coating is attributed to the strong development of hydrogen. The cracks can be avoided by raising the temperature, reducing the current density to below 20 amps/dm², or adding boric acid. By a suitable choice of working conditions and concentrations, the deposition potentials of the two metals can be made virtually equal. 19839

5.3.4

Outline of the Chemistry Involved in the Process of Catalytic Nickel Deposition from Aqueous Solution. Pt. IV. G. Gutzeit. Plating, **47**, No. 1, 63-70 (1960).

Temperature in the Kanigen process should be 95 C or above. The optimum Ni^{2+}: $[H_2PO_2^-]$ ratio is 0.3-0.4M. An organic chelating agent complexes all the Ni^{2+} to prevent the precipitation of nickel orthophosphite; lactic or malic acids are suitable. An "exaltant" is added to increase deposition rates to 1.0 mil/h or more, counter-acting the slowing effect of the chelating agents. Controlled trace amounts of stabilizers, such as thiourea or thiosulfates, prevent solution decomposition. However, stabilizer concentration is critical since higher concentration inhibit deposition. 33 references.—MA. 20075

5.3.4, 6.3.17

Electroplated Metals on Uranium for Aluminum Cladding. John G. Beach, William C. Schickner, Dolores Hopkinson and Charles L. Faust. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., BMI-996, May 4, 1955 (Declassified Jan. 8, 1960), 28 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C.

Study of electroplated metals on uranium for aluminum cladding has defined the effects of several processing variables on the corrosion resistance. The

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TP-1D Sour Oil Well Corrosion. *Corrosion*, August, 1952, issue. $1.50 Per Copy.

TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion.) (Pub. 52-3) NACE Members $3.50; Others $5.00 Per Copy.

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quality of the uranium and the quality of the aluminum-nickel bond were important. Heat treatment and vacuum outgassing of the nickel-plated uranium prior to aluminum cladding were beneficial, and minimizing the amount of air present in the hot-press assembly was desirable. Variation in the steps for electroplating on uranium did not affect the corrosion resistance of aluminum-clad uranium. (auth)—NSA. 20085

5.3.4

Practical Aspects of Hard-Chromium Plating. Pts. I, II. C. F. Corfe. Electroplating, **13,** Nos. 1, 2; 48-52, 69 (1960).

Pt. I. Corfe describes plant and discusses cleaning, pickling and rinsing techniques, jigging, and the position and shape of anodes. The silico-fluoride solution is preferred to the orthodox $HCrO_4$-H_2SO_4 bath where heavy deposits are required. Other advantages are increased current efficiency and production of smoother and harder deposits.

Pt. II. Steel to be hard-chromium plated is anodically etched in $HCrO_4$, H_2SO_4 or $(COOH)_2$ except where a highly polished surface is required. Plating of aluminum is preceded by a double ZnO_2^{2-} treatment; plating of titanium, magnesium and copper and its alloys is described. The silicofluoride bath has certain advantages over the orthodox type.—MA. 20215

5.3.2, 4.3.3

Continuous Immersion in Caustic Withstood by Chemical Nickel Lining. G. Weyermuller and R. Swandby. Wyandotte Chemical Corp. Chem. Processing, **23,** No. 2, 108-109 (1960) Feb.

Instead of 1½ year service life of organic coatings, Kanigen Ni-lined tanks will last 10 years (and possibly 20 years) in continuous immersion service with 74% caustic at 260 F.—INCO. 20254

5.3.4

Vapour Plating by Vacuum Evaporation. B. J. Williams. Electroplating & Metal Finishing, **13,** No. 7, 247-251 (1960) July.

Outlines method of producing thick vacuum deposits of cadmium on aircraft fittings, consumer hardware, automobile components, etc., and describes work on corrosion resistance and adhesion of the coatings. Salt spray and tensile tests indicate that vacuum deposited cadmium is equal to electrodeposited cadmium in corrosion resistance and that its adhesion to high tensile steel is improved by evaporating on to grit blasted surface. Advantage of vacuum plating is avoidance of hydrogen embrittlement difficulties, but disadvantage is fact that adhesion is mechanical. Tables.—INCO. 20252

5.3.2, 8.4.5

Coating Uranium Dioxide Powders with Metallic Tungsten. Joseph H. Oxley, James F. Hannah, John M. Blocher, Jr. and Ivor E. Campbell. Ind. and Eng. Chem., **51,** No. 11, 1391-1394 (1959).

Multiphase nuclear-reactor fuel elements were devised for operation at high temperatures and ratings. One possible source material is W-coated UO_2. The coating technique consists of the hydrogen reduction of WCl_6 in a fluidized bed. The experimental results indicate that mechanical vibration was necessary for satisfactory fluidization; the optimum reduction temperature was 400 C, and excess hydrogen ratios above approximately 200 did not significantly increase the percent conversion. The main impurities in the tungsten coating are iron and chlorine. The coatings appeared to be adherent and no evidence of phase separation was found. —MA. 20937

5.3.2, 2.3.2, 6.2.3, 4.2.1

Corrosion Behavior of Decorative Copper, Nickel and Chromium Platings on Steel. (In German.) H. M. Heiling. Metall, **14,** 549-561 (1960) June.

Plated samples of steel sheet are exposed to the "Corrodkote" corrosion test—held in an atmosphere with 93-100% relative humidity at 38 C and covered with a paste containing kaolin, NH_4Cl, $Cu(NO_3)_2$, $FeCl_3$ and H_2O. Other samples are tested in an industrial atmosphere according to Kesternich (i.e. at 48 C, 100% humidity and with SO_2 and CO_2 present). Potential measurements. Micrographs. 33 references. —RML. 20671

5.3.3

Standardizing the Preparation of Electrodeposits on Test Panels for Corrosion Testing. A. K. Graham and H. L. Pinkerton. Proc. Am. Soc. Testing Materials **59,** 317-329 (1959).

The paper describes the preparation of specifications for the plating of corrosion test panels. All operations from the polishing of the basis metal to the buffing of the final deposit must be done under laboratory conditions. Calibration runs should be made to establish quality control standards for every operation. 5 figures, 4 tables. —ZDA. 21348

5.3.4, 2.3.2, 2.2.2

Corrosion-Resistance of Intermediate Copper Electrodeposits on Steel from Acid and Cyanide Baths. H. W. Dettner. Metalloberfläche, **13,** No. 7, 193-195 (1959).

Angle-steel test pieces covered with a Cu 15/bright Ni 15/Cr 0.8 μ coating were exposed to industrial atmospheres, alternating climate, salt-spray, alternate immersion, and weathering tests. Accelerated corrosion occurred within the angle of the specimen when the intermediate Cu coating was deposited from acid baths. This did not occur when cyanide electrolytes were used, which, therefore, appear to have better throwing power than the acid electrolytes which leave unfilled cracks and other defects tending to retain electrolyte, wash water, & etc., and causing accelerated attack. —MA. 20595

5.3.4, 3.2.2

Hydrogen Embrittlement of High-Strength Steels During Cadmium, Chromium and Electroless Nickel Plating. W. L. Cotton. Boeing Airplane Co. Plating, **47,** No. 2, 169-175 (1960) Feb.

Embrittlement resulting from Cd, Cr and electroless Ni plating was evaluated using 5 representative aircraft steels (AMS 6427, 6407 and 6418, AISI 4340 and 4340-1.5 Si) heat-treated to various

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tensile strengths up to 300,000 psi. This was done by static loading plated specimens to minimum of 75% of notched ultimate tensile strength and determining time to failure. Following low-embrittlement processes were proved satisfactory for low-carbon alloy steels heat-treated up to 280,000 psi strength level: "High Efficiency" cadmium plating; passivation of cadmium plating to meet corrosion requirements of Federal Specification QQ-P-416a; hard chromium plating and electroless Ni plating; each of platings followed by 23 hrs. bake at 375 F. Following processes were proved satisfactory for plating high-Si AISI 4340 heat-treated in range 270,000-300,000 psi: conventional bright Cd plating followed by 23 hrs. bake at 375 F; hard Cr plating and electroless Ni, each followed by 3 hr. bake at 550 F. Tables, graph, 9 references.—INCO. 20203

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5.3.4

Nickel-Aluminum Alloy Coatings Produced by Electrodeposition and Diffusion. Dwight E. Couch and Jean H. Connor. National Bureau of Standards. J. Electrochem. Soc., **107,** 272-276 (1960) April.

Nickel-aluminum alloy coatings were produced by diffusion of aluminum electrodeposited over nickel. The aluminum was plated from baths operated at 25 to 1000 C. The alloys were much harder than nickel and were superior to nickel coatings in salt spray, atmospheric exposure, and air oxidation tests. Attempts to codeposit the two metals were not successful. (auth)—NSA. 20204

5.3.4

Development of Duplex Nickel Plating Process. M. M. Beckwith. Harshaw Chemical Co. Paper before Am. Zinc Inst. Plating Symp., Detroit, November 12, 1959. Plating, **47,** No. 4, 402-404 (1960) April.

In 1945, purpose of duplex nickel coating was not concerned with corrosion resistance but rather an attempt to eliminate buffing operations after nickel plating and before chromium plating. In 1953 studies were made regarding comparison of corrosion resistance of bright, buffed Watts, buffed semi-bright and duplex nickel cotaings, and first large bumper installation with duplex was started. Superior corrosion resistance of duplex system compared to bright nickel single coating was basis for renewed activity in 1957 in duplex coatings of zinc base die castings. Corrosion test results are reviewed and corrosion behavior phenomena of duplex nickel coating clarified.—INCO. 20236

5.3.4, 7.2

Pipes Protected Inside and Outside by Diffusion Chromium Plating. (In Dutch.) G. Becker. Metalen, **15,** 2-4 (1960) Jan. 15.

Process produces a 30% chromium surface at approximately 1000 C in closed retorts. This percentage decreases gradually with the depth. A minimum of 13% chromium is required for corrosion protection. Steels having a low carbon content are most suitable for plating by this process.—RML. 20284

5.3.4

Why Not Metallize to Prevent Corrosion. H. Thomasson. Can. Metalworking, **22,** No. 6, 42-43 (1959) June.

Main virtue of metal spraying or metallizing is ability to deposit metal in almost any desired thickness on almost any surface. Worn areas can be built up by matching metal while corrosion is combatted by protective materials. One of the most favorable factors is freedom from overheating sprayed surfaces resulting in no adverse heat effects. Two distinct phases of process are surface preparation and applying new material. Five methods of surface preparation listed in most manuals are: groove and rotary roughening, rough threading, metallic spray bonding and blasting. Application of sprayed metal is done with a gun that feeds wire or powder into a fuel gas flame which then atomizes wire metal or melts metal powder and projects it at high velocity on to surface being coated. Great variety of metals can be applied by metal spraying including carbon steels, stainless steels in either straight chromium or 18-8 type, zinc, aluminum, copper and its alloys. Nickel is used whenever its excellent properties are required. Successful applications of process are mentioned.—INCO. 18607

5.8 Inhibitors and Passivators

5.8.4

Anti-Corrosive Properties of Addition Compounds of Fatty Acids with Aliphatic Amines and Diamines. (In Italian.) G. Jacini, M. B. Raffel, D. Rossetti and A. Arpino. Olii minerali, grassi e saponi, colori e vernici, **35,** 399-401 (1958).

Anticorrosive properties of 23 salts of long-chain fatty acids with amines, diamines, or aminoalcohols were tested by immersing a steel cylinder in an aqueous emulsion of lubricating oil. Ethylenediamine palmitate and hexamethylenediamine palmitate were among the more effective additives. 18809

5.8.4, 4.6.1, 7.4.1

Chromate Inhibitors Furnish Effective Low-Cost Corrosion Control. G. Weyermuller. Chem. Processing, **22,** No. 11, 56-59 (1959) Nov.

At Nalco Chemical Co., chromate inhibitors are made more effective by blending with other chemicals that improve results achieved in water treatment program, including freedom from fouling, greater corrosion inhibition, and prevention of deposits on metal surfaces. Using several chemicals in synergistic combination decreases quantity of inhibitor necessary. Description is given for treatment of open system (cooling tower) and closed system (compressor cooling through heat exchanger). Inhibitors are produced as pellets, balls or powder.—INCO. 18621

5.8.3, 6.4.2

Effect of Dextrin Inhibitor on the Corrosion Potentials of Aluminum in Alkaline Solutions. J. Sundararajan and T. L. Rama Char. Corrosion Prevention and Control, **6,** No. 1, 41-42 (1959) Jan.

Potentials of aluminum in sodium hydroxide solutions (0.1-0.3N) with varying concentration of dextrin (0.6-30 g/l) were measured until steady state values were reached (2 hours). Table gives values for difference in steady state potential ΔE on hydrogen scale for various inhibitor concentrations. Potential increment is quite large at low concentration of inhibitor and differences become smaller with increasing concentration.—INCO. 18573

5.8.2, 3.4.8

Corrosion Inhibition by Hexametaphosphate in the Presence of Bivalent Metallic Ions. Koso Takeuchi. Corrosion Engineering (Japan), **8,** No. 4, 147-149 (1959) April.

Studied inhibitive effect of sodium hexametaphosphate on corrosion of steel in presence of bivalent metallic ion such as Ca^{++}, Zn^{++}, Ni^{++}, Cd^{++}, etc. A batch test was conducted with a 100 ppm sodium chloride solution. The inhibitive action was found to be dependent on

the ratio of metalliction to sodium hexametaphosphate, and the optimum ratio of Ca^{++}, Zn^{++}, and Ni^{++}, was found to be respectively of 50, 25 and 60 parts to 100 parts of sodium hexametaphosphate. Best inhibition was attained with a concentration of sodium hexametaphosphate lying between 75 ppm and 100 ppm, and a pH range from 6 to 9. The influence of temperature was also studied. 18590

5.8.2, 8.9.5

Use of Corrosion Inhibitors for Protecting the Interior Surfaces of the Tanks in Tankers. (In Russian.) M. Karepina and B. Sushkov. Morskoi Flot (Maritime Fleet), No. 12, 15-16 (1958).

Corrosion inhibitor "Amba" (made from ammonia and benzoic acid) has shown in tankers that steel SKhL-1 remains unattacked in the gas phase; in the fuel phase the corrosion rate is reduced to 1/48, and in the system water-fuel it is reduced to ⅓ of the original value. The corrosion rate of brass in fuel containing 0.01% of the inhibitor is reduced by 27%. With 0.5% of the inhibitor in gasoline, no corrosion is noted. 18813

5.8.3, 6.2.2

Anodic and Cathodic Polarization Phenomena with the Inhibition of the Acid Corrosion of Iron. (In German.) W. Machu and H. I. Morcos. Cairo Univ. Werkstoffe u. Korrosion, **11**, No. 3, 156-162 (1960) Mar.

It is shown that the inhibitors are primarily adsorbed or chemically fixed by the local anodes and only later by the local cathodes. These phenomena are exclusively governed by the energy conditions on the metal surface, and not by the sign of the inhibitor particles. The adsorption takes place in two phases as it were. Good inhibitors show, apart from higher ohmic resistances, stronger anodic and cathodic polarizations. If the adsorption happens to take place, predominantly, at the local anode, the inhibiting effects and film resistances are lower. A high film resistance is always associated with a stronger cathodic polarization. Poor inhibitors do not survive the first phase of adsorption to the local anodes. With good inhibitors, however, this phase is overcome very soon, and even with very low concentrations of approximately 0.01 gram per litre, and over. The phenomena at the local anode are retarded by the blocking of the active centers while those at the local cathode are slowed down or arrested by a coherent layer of the inhibitor of higher ohmic resistance. 19305

5.8.2, 4.6.4, 8.1.1

Sodium Nitrite as an Unpredictable Corrosion Inhibitor. S. Sussman, O. Nowakowski and J. J. Constantino. Paper before American Chemical Society, New York, March, 1958. Ind. & Eng. Chem., **51**, No. 4, 581-584 (1959) April.

Absence of color and limited toxicity of sodium nitrite make it attractive as a corrosion inhibitor for air conditioning cooling waters. Initial laboratory tests indicated good corrosion control under economical operating conditions, but further tests, inspired by unexpected field results, showed significantly reduced inhibition with increased sulfate concentrations. It is not known whether this is the only such factor, in addition to chlorides and low pH. Test coupon results from nitrite-treated operating equipment were often inconsistent with those expected on basis of laboratory tests and published data. Because causes of these inconsistencies have not been established, caution is indicated in use of sodium nitrite as an inhibitor in evaporative cooling systems. Test coupon materials included SAE 1015 hot rolled steel, brass, copper, aluminum, solder (half lead and half tin), and soldered copper. Water used in laboratory tests was New York City's Croton supply, with and without additions of sodium chloride, sodium sulfate, or both; distilled water was also used. Data are tabulated. Photos of test coupons, 11 references.—INCO. 18567

5.8.4, 6.4.2

Effect of Some Organic Compounds in the Anodic Oxidation of Aluminum. (In Russian.) L. Donev and L. Boyadzhiev. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **32**, No. 9, 2031-2034 (1959). Translation Available from Associated Technical Services, P. O. Box 271, East Orange, New Jersey.

Ethanol, glycerol and aniline hydrosulphate tested as inhibitors with the latter proving the most effective. 8 references.—RML. 19092

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5, 4.4.9

Corrosion of Metals in Thionyl Chloride. (In Russian.) V. A. Tomov, Yu. A. Babkin and I. M. Balandin. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **22**, 1167-1169 (1959) May. English Translation of Journal Available from Consultants Bureau, Inc., 227 West 17th Street, New York 11, New York.

E.T. 461 (steel) possesses a high corrosion resistance, the rate being 0.01 mm/year. An effective and cheaper substitute is provided by 18-8 chromium-nickel-titanium steel possessing high corrosion resistance (0.02 mm/year) high plasticity, good weldability and high impact strength.—RML. 18562

6.2.5, 4.3.2, 3.4.8

Behavior of 18-8 Stainless Steel in 20° Bé HNO_3, Containing Chlorine. Anna Prati. Istituto Sperimentale dei Metalli Leggeri. Chim. e ind. (Milan), **42**, 145-150 (1960) Feb. (In Italian.)

Results of some laboratory tests carried out in order to determine the lowest content of chloride, which can be tolerated in regard to the corrosion resistance, effects of the material (stainless steel 18/8) in an HNO_3, absorption vessel where the concentration of the acid was at 20° Bé, are described. The minimum chlorine content practically tolerable resulted to be 9.2 g/l. (auth)—NSA. 20098

6.2.5, 4.3.2, 3.8.3, 3.5.9

Stainless-Steel Corrosion by Dilute Nitric Acid at Elevated Temperatures and Pressures. M. L. Pearce and V. S. Griffiths. Corrosion Technology, **7**, No. 5, 142-145, 162 (1960) May.

Corrosion resistance of 18-8 to HNO_3 over concentration range 0.01-1.4 at 300 and 350 C was investigated. In pure HNO_3 solutions, rate of corrosion for passive condition is 1.5 ± 1.0 mg/sq cm yr. and is constant for all acid concentrations studied. Effects of time and temperature are discussed. Rate of corrosion for passive conditions is unaffected by increase in temperature or small quantities of oxidizing ions (Ce and Cr ions), but is increased in presence of 10 g/l of uranium. Corrosion in vapor phase was insignificant, though severe corrosion occurs at vapor-liquid interface. Weight-technique was used for bulk of determinations, but alternative electrochemical technique for investigating was studied with good results. Graphs, 11 references.—INCO. 20033

6.2.2, 3.7.2

Effect of the Chromium Content on the Electrochemical Behavior and Resistance to Corrosion of Iron-Chromium Alloys. (In Russian.) G. M. Florianovich and J. M. Kolotyrkin. Karpov Scientific Res. Inst. Doklady Akad. Nauk S.S.S.R., **130**, 585-588 (1960) Jan. 21.

The influence of chromium content on iron-chromium alloy corrosion was determined by a potentiometric method combined with a colorimetric method of determining corrosion product concentrations in solution. The measurements were carried out in 0.1N sulfuric acid solution in a nitrogen atmosphere. Curves of dissolution rate as a function of chromium content were plotted for Fe-Cr alloys with 0.1 to 35% Cr and up to 0.4% Ni. An increased content of Cr increases the dissolution rate in sulfuric acid at potentials close to stationary and decreases it with intermediate potential values, especially at the transition point from 12 to 13% Cr.—NSA. 20099

6.2.5, 4.2.3, 3.5.2

Oxidation of Heat-Resistant Steels; Effect of Alkaline Sulphate Deposits at the Simultaneous Presence of Traces of Sulfur Trioxide in Furnace Gases. (In German.) A. Rahmel. Arch. Eisenhuttenw., **31**, 59-65 (1960) Jan. Translation available from The Iron and Steel Inst., 4 Grosvenor Gardens, London, S. W. 1, England. (Order BISITS 1659.)

Attack of corrosive deposits on heat-resistant steels. Testing equipment and

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method of testing. Influence of temperature, time and sulfur (VI) oxide content of furnace gases on the loss in weight of X 8 CrNiNb 16 13 steel embedded in potassium sulfate with and without 5% Fe_2O_3. Comparative investigations on some steels for high temperature service and some non-scaling steels. Discussion of results. Conclusions. (auth)—TT. 20007

6.2.5, 3.4.8, 4.3.2

Effect of Halogen Ions on the Corrosion of Stainless Steel 18-8 in H_2SO_4. (In Russian.) Bao-din Khua, Sin-su Shen, Z. A. Iofa and E. I. Mikhailova. Doklady Akad. Nauk S.S.S.R., **130,** 129-132 (1960) Jan. 1.

Measurements were made of the rates of 18-8 stainless steel (9.3% Ni, 16.8% Cr, 0.14% C, 0.84% Mn, 0.05% Ti, 0.019% S, and 0.013% P) solubility in 10 *N* sulfuric acid as functions of salt concentration (NaCl, KBr and KI). The polarization curves in pure 10 *N* sulfuric acid and with salt admixtures were plotted at room temperature.—NSA. 19949

6.2.5, 3.7.4, 3.7.2, 4.6.11

Effect of Composition and Structural Condition on the Resistance of 18-2 Chrome-Nickel Steels to Electrochemical Attack. G. Newcombe. Metallurgia, **61,** No. 365, 107-112 (1960) March.

Influence of chemical composition on percentage delta-ferrite present in microstructure of 18-2 Cr-Ni steels (to specification B.S. 970 En. 57) is discussed and has been related to factor of corrosion resistance. An investigation into failure of two pump shafts which were directly connected with a bronze impeller and were operating in a sea-water environment, and a series of immersion tests of selected steels coupled to a copper-base alloy (86/7/5/2 gunmetal) in seawater, produced information on mechanism of breakdown and indicate a superior resistance to attack when a wholly martensitic structure is achieved. An increase in percentage ferrite will result in a corresponding decrease in resistance to this form of attack. Main role of addition of 2 nickel to En. 57 steels is to give a greater hardening capacity. However, nickel decreases percentage delta-ferrite, and in this connection, increases corrosion resistance. Steels of higher C (0.20-0.25) and nickel (2.0-3.0) contents exhibit a homogeneous martensitic structure in fully treated condition. Photos, photomicrographs.—INCO. 19993

6.2.5, 3.5.9, 8.9.1

Development of a Corrosion-Resistant Bearing Steel for Service in Aircraft at Temperatures Up to 1,000 F. (Period covered): April 1958-July 1959. G. Steven and T. V. Philip. Crucible Steel Co. of America. U. S. Wright Air Development Center, Technical Rept 59-390, July 24, 1959, 68 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion resistance has been added to the high initial hardness, adequate temper resistance (600 to 900 F), and good dimensional stability of a high-speed type bearing alloy. To produce secondary hardening, the base composition of a quench hardenable stainless steel, 440 C, was modified with V, W, Mo and Co. The following composition is recommended for use as a stainless bearing steel for 500 hr of operation up to 900 F: 1.10 to 1.15% C, 0.15% max Mn, 0.15% max Si, 13.5 to 14.5% Cr, 2.5 to 3.0% V, 2.0 to 2.5% W, 3.75 to 4.25% Mc, and 5.0 to 5.5% Co. For best performance, the steel should be heat-treated as follows: heat to 2,200 F, oil quench, and refrigerate to —105 F. Rockwell "C" 66 is achieved (2% retained austenite) by tempering the steel for 1 + 1 + 2 hr at 1,000 F with intermediate sub-zero cooling after the first and second draws. Tempering twice for 2 hr. at 1,000 F also results in a useful structure. After 500 hr. at 900 F the hardness drops to R_c 65 (hot hardness of R_c 57), and the structure contracts 13 μ in./in. After three cycles of a water-vapor corrosion test, the surface of fully heat-treated WADC66 is only slightly more pitted than that of annealed 430 stainless steel. (auth)—NSA. 20188

6.2.5, 8.4.5, 2.3.8

Thorex Pilot Plant Corrosion Studies. Pt. II. Corrosion of Types 304L, 309SCb and 347 Stainless Steel During Development and Production-Development Periods. J. L. English. Oak Ridge National Laboratory. U. S. Atomic Energy Commission Publication, ORNL-2844, January 20, 1960, 50 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C.

Corrosion data for types 304L, 309SCb and 347 stainless steel were obtained in a number of process vessels in the ORNL Thorex pilot plant during the development and the production-development periods of operation occurring between December 1954 and September 1956. Stressed corrosion-test specimens were exposed in the batch dissolver tank, the feed adjustment tank, the BT vapor separator, the A-column feed tank, and the BTC catch tank. Generally, types 304L and 309SCb stainless steel exhibited comparable corrosion resistance in all environments examined. Most of the studies were conducted with these two alloys. Severe corrosion damage was encountered in the vapor phase of both the batch dissolver tank, operated at a maximum temperature of 115 C and the feed adjustment tank, operated at a maximum temperature of 155 C. Corrosion rates for types 304L and 309SCb stainless steel varied from approximately 30 to 55 mpy in the batch dissolver tank during the development and the production-development periods. Vapor-phase corrosion rates in the feed adjustment tank during the last half of the development period ranged from 85-100 mpy. Severe corrosion attack was experienced also in the BT vapor separator, which operated at a maximum temperature of 115 C. Rates were 30-55 mpy for type 304L stainless steel, 25 mpy for type 309SCb stainless steel, and a maximum rate of 150 mpy for a composite specimen of types 309SCb and 347 stainless steel. Solution-phase corrosion rates for types 304L and 309SCb stainless steel in the batch dissolver tank ranged from 13-28 mpy, with the lower rates observed on the type 309SCb steel. The latter corroded at an average rate of 41 mpy in the feed adjustment tank, however. No data were available for type 304L stainless steel in the solution phase of this vessel. The corrosion of types 304L and 347 stainless steel was negligible in the A-column feed tank and the BTC catch tank; observed rates were less than 0.1 mpy. (auth)—NSA. 20143

6.2.5, 3.7.4, 2.3.9

Resistance to Corrosion of Stainless Steels. Pt. 11. Sigma Phase. (In Italian.) Carlo Belvedere. l'Acciaio Inossidabile, **26,** 177-221 (1959) Oct.

Identification of the sigma phase by metallography, electrolysis, acid reactors, X-ray and magnetic permeability tests. Formation and influence and properties of the sigma phase in the systems Fe-Cr, Fe-Cr-Ni, Cr-Ni steel with Mo, Fe-Cr-Mn, stainless steel and austenitic steels of Cr-Mn. A phase (called CHI) is discovered in stainless steel Cr-Ni containing Mo. 53 references.—RML. 20288

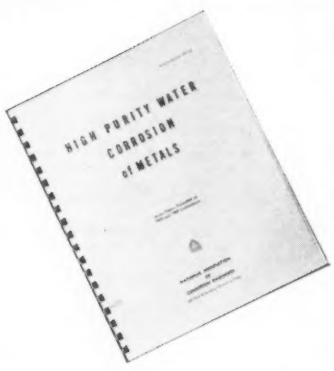
6.2.5, 4.3.2, 8.4.5

Corrosion of Stainless Steel in Thorex Process Solutions. Patricia M. Kranzlein, M. L. Holzworth and J. A. Snyder. E. I. du Pont de Nemours & Co. U. S. Atomic Energy Commission Pubn., DP-429, December, 1959, 15 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion for 304L and 309SCb stainless steel was studied in HF-HNO_3 solutions proposed for the Thorex process. Except for the dissolving and waste evaporation steps in the Thorex process, corrosion of 304L and 309SCb is not expected to exceed that experienced in the Purex process. To minimize the high initial corrosion rate of 309SCb in the boiling HF-HNO_3 dissolving solution, a heel of thorium should be maintained in the dissolver. The corrosion rate of 304L in the low activity waste evaporator can be reduced by adding one mole of aluminum per mole of fluoride to the evaporator feed. (auth)—NSA. 19946

6.2.5, 3.2.2, 3.5.3, 4.3.2

Four New Stainless Alloys. N. S. Mott. Copper Alloy Corp. Iron Age, **183,** No. 16, 118-121 (1959) April 16.

PH-55 alloys, a new series of Mo-containing 18-8 type alloys, provide higher strength and hardness with greater re-

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sistance to corrosion (especially pitting corrosion) and erosion effects of velocity and suspended abrasives which intensify corrosive damage. Although PH-55 series are primarily produced in cast form, rolled bar stock has been made of PH-55A and PH-55C on an experimental basis. Chemical compositions and mechanical properties of PH-55A, PH-55B, PH-55C and PH-55D in cast form are tabulated, as are effects of aging on hardness and mechanical properties of wrought PH alloys. Table gives corrosion rates of PH alloys PH-55A, PH-55B, PH-55C and CF-8M in sulfuric, hydrochloric, nitric, acetic and phosphoric acids, Ca hypochlorite and ferric chloride. Photomicrographs.—INCO. 19871

8. INDUSTRIES

8.4 Group 4

8.4.5, 6.3.17, 6.4.2, 6.4.4

IAEA Symposium: Fabrication of Fuel Elements with Special Emphasis on Cladding Materials, Vienna, May 10-13. V. W. Eldred. Nuclear Engineering, **5**, 367-368 (1960) August.

This report includes the following items of interest: Study of BR-1 prototype fuel elements of natural uranium with Ni-bonding and Al-cladding, by D. Tytgat; Investigation of some Al alloys as cladding materials in water-cooled reactors for district heating and process steam, by K. Hannerz, R. Lindblad and A. W. Magnusson; Application of sinter aluminum as cladding material for fuel elements, by K. E. Mann and B. Boudouresque; Contribution to the diffusion and corrosion behavior and creep strength of aluminum powder products, by H. W. Schleicher, R. Weber and U. Zwicker; Welding of plugs and shieldings made of Mg alloys, by P. Thome and C. Bridoux and Compatibility of various magnesium alloys with CO_2 under pressure between 400 and 600 C, by P. Baque, R. Darras and C. Chevilliard.—LMB. 20581

8.4.5, 6.2.5, 6.3.10, 3.5.9

Structural Materials for Thermal Nuclear Reactors Operating at About 1950 F With Air as a Coolant. Walston Chubb, John A. De Mastry, Seymour G. Epstein, Roy W. Endebrock, Donald P. Moak and Ronald F. Dickerson. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., BMI-X-159, July 20, 1960, 76 pp. Available from Office of Technical Services, Washington, D. C.

Data from a survey of the literature on all refractory metals including stainless steels and nickel-, chromium-, and niobium-base alloys were reviewed and assembled for the purpose of obtaining an estimate of the potential materials for use as cladding materials in a nuclear reactor operating in air at 1950 F. Criteria established for selection of materials include a life of 10,000 hr at a stress of 1000 psi, a loss of material by oxidation of less than 0.010 in., and a macroscopic thermal-neutron-capture cross section of less than about 0.38 $cm.^{-1}$ Some austenitic stainless steels and nickel-base alloys appear to have properties which meet the design criteria. It is recommended that an experimental program be initiated to check the suitability of these or similar materials with respect to these design criteria. It is also recommended that a supporting effort be directed toward developing composites of strong chromium or niobium alloys clad with materials of the ferritic stainless steel type which are oxidation resistant but are unable to support appreciable stress at elevated temperatures. (auth) —NSA. 20555

8.4.5, 6.2.5, 6.3.15, 6.3.20

Examination of Corrosion Specimens from Slurry Blanket Mockup Runs SM-6 Through SM-9. R. B. Gallaher, S. A. Reed and G. G. Warner. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-60-5-137, May 26, 1960, 12 pp. Available from Office of Technical Services, Washington 25, D. C.

Low attack rates (0.1 to 0.5 mpy) were displayed by coupon specimens of Type 347 stainless steel, titanium RC-55, and Zircaloy-2 which were exposed for 2877.5 hr. in an oxygenated slurry of Th-8% U oxide, 116.5 hr. in water, 6.9 hr. in 5% HNO_3, and 4.3 hr. in 3% trisodium phosphate during runs SM-6 through SM-9 in the slurry blanket mockup. The leading coupon of Type 347 stainless steel showed a slightly higher rate than the other stainless steel coupons due to entrance effects. Specimens of SA-212-B carbon steel displayed average attack rates of 2.9 mpy. (auth) —NSA. 20637

8.4.5, 4.7, 5.3.4

Cladding Survey for the Enrico Fermi Reactor U-15 wt.% Mo Base Dispersion-Type Fuel Element. M. M. Martin and R. J. Beaver. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-60-4-118, April 29, 1960, 39 pp. Available from Office of Technical Services, Washington, D. C.

Potential cladding materials for a flat-plate fuel element containing a dispersion of UC or UO_2 in U-15 wt.% Mo alloy were surveyed on the bases of compatibility with the missile compounds, matrix material, protective cover materials, and liquid sodium as well as the feasibility of fabricating fuel plates by roll cladding. Radiative-capture cross sections, thermodynamic data, eutectic and intermediate compound formation, mechanical properties, and corrosion by 1000 F sodium are reported for austenitic stainless steels, chromium, nickel, niobium, molybdenum, tantalum, vanadium and zirconium. It was recommended that "A" nickel (molybdenum barrier), Zr-3 wt.% Al, Nb-2 wt.% Cr, and Fansteel 82 be selected for investigation. (auth) —NSA. 20753

8.4.1, 2.4.2

Monitoring Corrosion in Coal Chemicals Production. R. J. Schmitt and R. R. Christian. Ind. and Eng. Chem. (I/EC), **52**, 71A-72A, 74A (1960) Nov.

Use of corrosion probes in coal chemicals production to measure the change in electrical resistance associated with metal loss. Probes are available for use at temperatures up to 1000 F. and at pressures of 10,000 psig, and with a tube type element, measurement of corrosion rate of 0.02 in. per year can usually be made from readings taken only several hours apart. —RML. 21036

8.4.5, 1.3, 1.2.2

Status Report on Control Rod Materials Research and Development Program. C. G. Andre, A. N. Holden, W. J. Ozeroff and T. J. Pashos. General Electric Co., Vallecitos Atomic Lab., Pleasanton, Calif. U. S. Atomic Energy Commission Pubn., GEAP-3355, Feb. 8,

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T-5A-3 Corrosion by Acetic Acid—A Report of NACE Task Group T-5A-3 On Corrosion by Acetic Acid. Pub. 57-25. Per Copy $2.50.

T-5A-4 A Bibliography on Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry. (Compiled by Task Group T-5A-4 on Chlorine.) Pub. 56-2. Per Copy $2.00.

T-5A-4 Summary of Replies to Questionnaire on Handling of Chlorine Mixtures—A Report of NACE Task Group T-5A-4 on Chlorine. Pub. 59-15. Per Copy $1.50.

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1960, 55 pp. Available from Office of Technical Services, Washington, D. C.

Material presented to the AEC in a review of the status of the Control Rod Materials Research and Development Program is listed. The purpose of this project is to provide scientific data and technology for control rod materials to be used in thermal and epithermal reactors. The materials should be suitable for use over a wide range of temperatures, extended operating periods, and various coolant environments. There are included a comparative and economic evaluation of control materials, corrosion studies, measurements of physical properties, experiments carried out on different control rod materials and a survey of current and proposed work. —NSA. 21111

8.4.5, 6.6.6, 6.7.2

Properties of Ceramic and Cermet Fuels for Sodium Graphite Reactors. N. R. Koenig and B. A. Webb. Atomics International, Div. of North American Aviation. U. S. Atomic Energy Commission Pubn., NAA-SR-3880, June 30, 1960, 50 pp. Available from Office of Technical Services, Washington, D. C.

Nuclear materials of interest as potential reactor fuels for sodium graphite reactors are reviewed to select those which appear most feasible for high-temperature, long-burnup application. Fuel properties such as melting point, thermal neutron absorption cross section, uranium content, chemical and physical properties, and fabrication details are presented. Other factors such as expected burnup capabilities, required enrichments, and conversion ratios were compared. A program is currently in progress to evaluate promising nuclear fuels. Fuel materials under consideration include the uranium compounds: uranium dioxide, uranium monocarbide, borides, sulfides, aluminide, nitrides, silicides and phosphides. Various cermets are under consideration. These include dispersions of uranium compounds in matrices of uranium, uranium alloys, thorium, and thorium alloys. Included among the uranium alloy matrices are binary and ternary combinations of uranium with niobium, molybdenum, and zirconium. (auth)—NSA. 21447

8.4.5

Sulfur Cooled Power Reactor Study. Quarterly Report No. 1 for Period October 1, 1959 to January 1, 1960, 11 pp. U. S. Atomic Energy Commission Pubn., Aerojet General Nucleonics-150. Available from Office of Technical Services, Washington, D. C.

A literature search was carried out and a summary of reported results are included. Sealed, refluxing sulfur capsules were partially immersed in a temperature-controlled salt bath to maintain constant temperature. The capsules were of Vycor approximately 13 mm ID, 17 mm OD, and 12 in. long. A number of capsules was tested, and the preliminary results are discussed. A schematic of the circulating dynamic heat transfer and corrosion loop is given.—NSA. 20399

8.4.5, 6.2.5, 4.3.2

Effects of Solution Composition on the Corrosion of the Redox H-4 Oxidizer. Norman D. Groves, Morris C. Fraser and William L. Walker. General Electric Co., Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-33374 (Del.), August 18, 1955 (Declassified with deletions Feb. 4, 1959), 19 pp. Available from Office of Technical Services, Washington, D. C.

Two series of tests were completed which were designed to evaluate the corrosion problem present in the Redox H-4 Oxidizer. The first series of tests involved exposing annealed coupons of Types 304L and 309SCb stainless steel to nine synthetic H-4 Oxidizer solutions. The solutions all contained UNH and had varying amounts of several oxidizing agents. The free nitric acid of the solutions ranged from 0.2 **M** acid to —0.2 **M** acid deficient. These exposures were all made at the boiling point of the respective solution and had an exposure time of five 48-hr periods. The second series of tests consisted of exposing sensitized specimens of Types 304L, 312 and 347 stainless steels under static conditions at the boiling point of three synthetic H-4 Oxidizer solutions and as heat transfer surfaces at temperatures of 140 C. The three solutions used contained UNH, 0.15 **M** sodium dichromate and either 0.2 **M**, 0.01 **M**, or —0.2 **M** nitric acid. The test duration was 336 hrs. A-55 titanium in the as-received condition was exposed in the manner described above (auth) —NSA. 21341

8.4.5

Corrosion Studies, Calcining Aqueous Radioactive Wastes. E. J. Tuthill and R. F. Domish. Brookhaven National Lab. Ind. Eng. Chem., **51**, 1471-1474 (1959) Dec.

A study was undertaken to measure the resistance of selected materials to corrosive conditions in calcination of simulated Zirconium waste solutions in rotary ball kilns. One investigation centered on use of a 325 and a 700 C kiln in series for forming nitrogen oxides separately from hydrogen fluoride. A second involving a single-kiln unit was made because several alloys showed favorable resistance in the high temperature (defluorination) unit of the double-kiln apparatus. At least four alloys were found suitable as materials of construction for single- or double-kiln apparatus for calcining radioactive wasts. (auth) —NSA. 20377

8.4.5, 5.7.6, 6.6.6

The Swimming Pool Reactors of 1000 KW, Melusine and Triton, Pt. VI. Purification of the Water and Casing. (In French.) P. Caron and R. Platzer. Bull. inform. sci, et tech. (Paris), No. 35, 53-60 (1959) Dec.

The principal characteristics of the water of swimming pool reactors are considered with respect to the requirements of biological protection, flexibility of utilization, neutron moderation, and corrosion. The two procedures generally

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utilized in the purification of water are distillation and ion exchange columns. The reasons for the choice of ion exchange columns for use in the Melusine and Triton are discussed, and the installations are described. The regeneration of the ion exchangers in the filling circuits and the purifiaction circuits is discussed. The operation of the filling and purification circuits is satisfactory after a year's experience. Casings are used in swimming pool reactors to prevent the pollution of the water by the concrete and not the corrosion of the concrete by the water. The types of casings used, metallic, elastomer veneers, continuous films, and ceramic are described, and the advantages and disadvantages are analyzed. In Melusine the casing is formed of tiles of enameled sandstone joined with a polyester resin. In Triton a ceramic casing joined with araldite is used. The behavior of each is briefly described. —NSA. 20513

8.4.5, 6.2.5, 6.3.11, 4.6.1

Corrosion Tests of Yankee Primary System Materials in High Temperature Dynamic Water. S. J. Cytron. Westinghouse Electric Corp. for Yankee Atomic Electric Co. U. S. Atomic Energy Commission Pubn., YAEC-153, September, 1959, 68 pp. Available from Office of Technical Services, Washington, D. C.

Three out-of-pile loop tests, varying in duration from 666 to 1284 hrs., were conducted in early 1959 under simulated Yankee reactor water chemistry conditions to evaluate the corrosion of various materials selected for use in the primary system of the Yankee reactor. The tests were performed at 600 F, 1800 to 1850 psig, at a flow velocity of 36 to 39 ft./sec, with and without lithium hydroxide additions for pH adjustment and with and without continuous ion exchange purification, in the case of the lithiated solution. Each test was started with a three-day exposure to 0.92 wt.% boric acid solution, followed by operation with the boric acid removed for the remainder of the test. From the data, stabilized corrosion rates and metal release rates were calculated for the austenitic stainless steels tested. The corrosion behavior of the control rod material (silver-indium-cadmium, 80:15:5 wt.%) in neutral and lithiated water was also studied. Nickel plating and adding small amounts of tin to the alloy were each found to improve the otherwise marginal corrosion resistance of the silver-indium-cadmium alloy. (auth) —NSA. 20547

8.4.5, 6.4.1, 6.3.20, 6.2.5, 4.6.1

Corrosion Problems of Canning Materials for Nuclear Fuel Elements. H. W. Schleicher. Werkstoffe u. Korrosion, **11**, No. 11 (Suppl.), 691-701 (1960) Nov.

The author deals with the more important corrosion phenomena liable to occur between canning materials and coolants of nuclear reactors. With reactors cooled by water or heavy water, Al and Zr are today the most important materials. Alloying additions greatly improve the corrosion behavior of these two metals. With water-cooled reactors working with enriched U, stainless steels are best suited. In metallic coolants, Zr and stainless steels have a high resistance, provided that suitable precautions are taken. In organic coolants serious corrosion problems are hardly encountered, though the H arising from the decomposition of these substances precludes the use of Zr. The problems encountered with gas-cooled reactors are varied. CO_2, now the most commonly used cooling gas, causes scale formation on most of the metallic canning materials at temperatures above ~ 500 C. Satisfactory practical experience has been gathered, in particular with magnesium alloys at temperatures up to ~ 450 C. With beryllium, it should even be possible to attain temperatures which are about 150 C higher. 21027

8.4.5, 6.2.3, 6.4.4

Corrosion Problems of Carbon Dioxide-Cooled Power Reactors. (In Czech.) Vratislav Rýpar. Akimov State Research Inst. of Shielding Materials, Prague. Jaderná energie, **6**, 192-199 (1960).

Corrosion problems in nuclear reactor construction and specific characteristics of these problems are dealt with. The analysis of chemical effects of coolant gas and kinetics of the interaction between gas and reactor materials are given. Oxidation of steel and magnesium alloys is of special interest. (auth) —NSA. 20846

8.4.5

Removal of EBWR Fuel Element Scale by Slurry Honing. Ira Charak. Argonne National Lab. U. S. Atomic Energy Commission Pubn., ANL-6216, Sept., 1960, 18 pp. Available from Office of Technical Services, Washington, D. C.

The scale deposit on the Experimental Boiling Water Reactor fuel plates can be removed by slurry honing the plates with an abrasive-water mixture. Problems inherent in any production operation of this type are discussed. Areas of continued investigation of the method are suggested. (auth) —NSA. 21242

8.4.3, 3.2.2, 3.5.8, 6.3.10, 6.2.5

Handling of Sour Well Fluids in the Pincher Creek Field. W. J. McGuire, L. W. Vollmer, R. C. Carlson and J. C. Stamberg. Paper before Can. Inst. Mining & Met., Ann. Mtg. Petroleum and Natural Gas Div., Calgary, May, 1960. Trans. Can. Inst. Mining and Met., **63**, 425-434 (1960). Can. Mining and Met. Bull., **53**, No. 580, 633-642 (1960) August.

Describes pilot production tests and program for evaluation of materials for handling natural gas and condensate containing aqueous H_2S, outlines Brit. American Oil Co. Ltd.'s operating experiences in Pincher Creek Field from standpoint of sulfide-stress cracking and corrosion (particularly pitting corrosion), and describes general design procedures and control measures employed to prevent sulfide-stress cracking and corrosion. Test specimens included coupons, steel spools, and stressed beam specimens. Among materials tested were: API Grades J-55, N-80 and "B"; 5 Ni steel; 5 Ni+1 Cr steel; 5 Ni+0.30 Mo steel; 9 Ni steel; 9 Ni+0.30 Ti steel; 5, 9 and 12 Cr steels; 70-30 Cu-Ni; Type 322; K-Monel; Monel; and Inconel. Detailed survey of actual equipment failures mentions Type 410 J-landing nipple, SAE 8620 locator keys (satisfactory performance), 17-4 PH steel flow beam, Types 304 and 316 wire lines, and Types 410 and 416 lever arm and pin in lever lock mechanism of gate valve. Problems of sulfide-stress cracking in welded connections and localized corrosion from chloride attack in austenitic and age-hardenable stainless steels are considered. Use of inhibitors is discussed. Components requiring high tensile strength and hardness characteristics should be made from K-Monel or properly heat-treated C-Mn-Mo and AISI 4140 steels. K-Monel, Monel, Inconel and Hastelloys are excellent for valve trim, springs, flow beams, and pressure controls. Illustrations. —INCO. 20760

8.4.5, 6.2.1, 6.3.13, 6.3.15

Corrosion Data from the ORNL Purex Pilot Plant Acid Recovery Equipment. J. W. Landry and J. W. Ullmann. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., ORNL-1210, March 25, 1952 (Declassified April 21, 1960), 69 pp. Available from Office of Technical Services, Washington, D. C.

Details are presented for the metallurgical examination of materials such as steels, Ta and Ti located throughout

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the ORNL Purex Pilot Plant Nitric Acid Recovery Unit. The corrosion data reported include the effect of decontamination treatments. Materials of construction suitable for the Purex acid recovery system have been determined. —NSA. 20696

8.4.5

Out-Of-Pile Experiments Related to Fast Reactor Safety. J. M. Morelle, W. J. McCarthy, Jr. and W. H. Jens. Westinghouse Electric Corp. Nuclear Sci. and Eng., **2**, No. 1, Suppl., 112-113 (1959) June.

Tests were performed to determine the time of containment of molten U-Mo alloy in a Zr cladding under conditions of constant temperature (1200 C) of varying cladding thicknesses (0.004 to 0.010 in.) and for three different materials (Zr, Ta and stainless steel) in contact with the fuel pins. Tests are being conducted to determine the mode of failure of irradiated and unirradiated fuel pins under conditions of constant heat input rate, using electrical resistance heating. Experiments are described which will determine how much heat can be removed from fuel subassemblies under conditions of two-phase flow and provide information on the flow transients to be expected after inception of boiling—NSA. 19917

8.4.5

Operation of HRP In-Pile Corrosion Test Loop 0-1-25. V. A. DeCarlo and R. A. Lorenz. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-60-8-120, August 24, 1960, 36 pp. Available from Office of Technical Services, Washington, D. C.

The performance and operation of Loop 0-1-25, an in-pile corrosion and coolant testing loop, in beam hole HN-1 of the ORNL Research Reactor are reported. The loop was operated for 2575 hr of uranyl sulfate fuel solution and 30,598 Mw-hr reactor operation. Mainstream temperature of the loop was 280 C and the pressurized temperature was operated at 295, 305, and 310 C. Performance of the loop, auxiliary equipment, and instrumentation was satisfactory. —NSA. 21279

8.4.3, 3.5.8, 6.2.1, 6.3.10, 5.8.4

Corrosion Problems at Lacq Sour Gas Field. Michel Estavoyer. J. Inst. Petrol., **46**, 223-233 (1960) July.

Design of installations including safety systems. Techniques and devices for testing tubing under combined stress and corrosion conditions. Special steels for resistance of sulfide stress-corrosion cracking. Stress-corrosion properties of 33 metals, including carbon steels, low and high-alloy steel, Monel and Inconel. Effectiveness of organic inhibitors. 11 references. —RML. 21301

8.4.5, 3.5.9, 6.3.17

New Development Tendencies in the Range of Reactor Fuel Elements. (In German.) O. Werner. Bundesanstalt für Materialprüfung. Kerntechnik, **2**, 192-200 (1960) June.

The transition from research reactors to power reactors is characterized by the use of higher operating temperatures in the power reactors. More rigid requirements for the fuel material and the fuel elements therefore appear. The properties of metallic uranium as fuel material and the improvement of these properties by alloying are reported. This improvement consists of the shape and dimensional stability in thermal cycling, stability with respect to neutron radiation, and the corrosion stability of the uranium by alloying. In this connection the requirements for fuel material in homogeneous reactors with liquid or solid fuel are given. (tr-auth)—NSA. 21219

8.4.5, 6.6.4

Materials and Fuel Element Development for the MGCR and HTGR Helium-Cooled Reactors. M. T. Simnad and W. P. Wallace. pp. 171-189 of "Gas-Cooled Reactors. A Symposium of The Franklin Institute and The American Nuclear Society, Delaware Valley Section, 1960, Philadelphia." Journal of the Franklin Inst., Philadelphia. Monograph No. 7, 1960.

A general review was made of research and development work on materials and fuel elements for the Marine Gas-cooled Reactor and the High-temperature Graphite Reactor. Although both of these reactors are helium-cooled, there are radical differences in the core design, therefore, separate research work is required for each reactor. The principal problems associated with the non-fuel materials include the choice of materials with adequate creep resistance at high temperatures, corrosion resistance to impurities in the coolant gas stream and absence of carburization in the presence of graphite. The possibilities of using impervious graphite as cladding material were discussed in some detail. The fuel element program for the MGCR included studies on ceramic dispersion type fuels. The HTGR fuel consists of dispersions of uranium carbide and thorium carbide in graphite. The problems associated with the development of these fuel elements and the results of the experiments in progress were presented. (auth) —NSA. 21023

8.4.5, 3.4.6, 3.2.2, 6.6.4, 6.2.5

Preliminary Evaluation of Materials for Use With a Gas-Suspension Coolant. G. E. Uhland. Babcock and Wilcox Co., Atomic Energy Div. U. S. Atomic Energy Commission Pubn., BAW-1200. July, 1960, 35 pp. Available from Office of Technical Services, Washington 25, D. C.

A literature survey was made as a preliminary to the gas-suspension materials compatibility studies. Its purpose was to gather information from related programs and evaluate it in terms of the gas-suspension concept. Nitrogen and helium are the carrier gases under active consideration. The reactions involving these gases were postulated. Information gathered showed that nitrogen can react with graphite and metals. It was also found that carbonaceous gases or graphite can embrittle metals through carburization. Helium is chemically inert, but creep strength of metals in a helium atmosphere is lower than in air. Methods for reducing the effects of or eliminating carburizing and nitriding are discussed. Off-gassing of graphite is shown to be a way of reducing gas impurities in an operating system. Powdered graphite was shown to release about ten times the gas volume released by block graphite. The formation of sigma (FeCr) was found to be a potential problem if stainless steels are used at high temperatures. It was concluded that nitriding and carburizing could be prevented in gas-cooled systems by means of barrier coatings, although the feasibility of such coatings for gas-suspension must be checked. Helium compatibility is termed a lesser

problem than nitrogen and carbon dioxide compatibility. Subjects that require further testing are cyanogen formation, possible erosion, sigma formation, nitriding and carburizing. (auth). —NSA. 21121

8.4.5

Semiworks Studies for the Reduction of Corrosion-Product Impurities in Ur-Plant UO_3. L. C. Amos, B. E. Kirkendall and K. L. Adler. General Electric Co., Hanford Atomic Products Operation. U. S. Atomic Energy Commission, HW-28492, July 2, 1953 (Declassified May 4, 1960), 10 pp. Available from Office of Technical Services, Washington, D. C.

Uranium recovery plant UO_3 powder frequently contains excessive amounts of iron, chromium and nickel. A description of the work carried out in semiworks equipment to define the factors contributing to high corrosion-product contamination is given. Recommendations for reducing the impurity level to meet specifications are included. —NSA. 21120

8.4.5

Preliminary Investigation of Alkaline Permanganate-Sodium Acid Sulfate for Decontamination of High Temperature Recirculating Systems. W. A. Oldham. General Electric Co., Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-60767, June 10, 1959, 8 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C.

Results of an investigation of an alkaline permanganate-sodium acid sulfate decontamination process for high-temperature recirculating systems are presented. Bench scale tests revealed consistent decontamination results equal or better than any currently used high-temperature process. The process is equally effective on activated corrosion and fission products on stainless and carbon steels. Composition specifications are given along with decontamination data and cost estimates. Corrosion data are also included. —NSA 19921

8.9 Group 9

8.9.3, 1.7.3

Pipeliners Answer Corrosion Questions. Gene Kinney. Oil and Gas J., **58**, 129-130 (1960) March 21.

Members of an NACE panel of Corrosion mitigation specialists answer questions prepared by other pipeliners. Questions pertain to the leapfrogging and balancing of electrodes, calculating groundbed resistance, locating shorts in cased crossings and interior pipeline coatings.—RML. 19801

8.9.1, 6.6.4, 6.3.6, 6.2.3, 6.2.5

Exploratory Materials and Missile-Nose-Shape Tests in a 4,000 F Supersonic Air Jet. Paul E. Purser and Russell N. Hopko. Langley Aeronautical Lab. U. S. National Advisory Committee Aeronautics, Research Memo L56J09, December 13, 1956 (Declassified September 1, 1959), 11 pp.

Some exploratory materials and nose-shape tests were made in a small supersonic air jet having a stagnation temperature of approximately 4,000 F. The materials considered included graphite, copper, carbon steel and stainless steel; the nose shapes included 90 total-angle cones, hemispherical-face cylinders, and flat-face cylinders. The graphite model suffered less damage in 17 sec than did the steel model in 10 sec, which indicates promise as a heat-sink material. The tests also indicated that flat-face cylinders appear to be subject to approximately one-half the aerodynamic heat input as are hemispherical-face cylinders. (auth.)—NSA. 19887

8.9.1, 6.4.1, 6.2.5, 5.9.4, 5.4.5

Corrosion Prevention in the Aerospace Industries. R. A. Cole. Corrosion Technology, **7**, No. 10, 320-324 (1960) Oct.

Reviews problems in prevention of corrosion in structures, engines and ancillary equipment of aircraft. Protection of light alloys, use of cladding (Alclad), anodic coatings, HAE process and MEL process for protection of Mg alloys, and anodic spray coatings are discussed. Developments in paints are covered. Epoxy resin paints are resistant to newer lubricants being used by jet aircraft. Stainless steel loses some of its corrosion resistance at flight speeds up to Mach 3. Bristol Type 188 all-stainless steel research aircraft may be painted for this reason. More comprehensive anti-corrosion measures required by carrier-based aircraft, flying boats and amphibian aircraft, and agricultural planes are considered. 18 references.—INCO. 21257

8.9.5, 5.2.2, 5.8.2, 8.4.3, 5.3.4

Corrosion Prevention in Oil Tankers. M. Seo and S. Takeshima. Paper before 5th World Petroleum Congress, 1959. Corrosion Prevention and Control, **7**, No. 7, 32-40, 44 (1960) July.

Discusses occurrence and forms of internal corrosion of tankers, application of cathodic protection, performance of Zn anodes and Al alloy anodes, effect of electro-coating and use of inhibitors. Corrosion of tanks is severest in case of clean ballast. Data are presented for Zn-alloy anodes in sea water, sea water/oil and ship tank tests. Zn-alloy anodes which contained In, Hg, Cd and Al, alone or combined, gave performance superior to that of high-purity Zn anodes. Zn anodes may be more economical than Mg anodes, but protective efficiency after tank is emptied is not so good as with Mg anodes. Additions of small amounts of In or Sn improve performance of Al anode. Electro-coating, deposited by initial high density current from galvano-line or impressed current system, is not so effective for tanks in black oil service, but 30% saving in required maintenance current is realized in case of sand blasted steel plates, by applying 40 A hr. current. Good protection can be effected for empty tanks. Electro-coating on rusted steel requires more current, and coating may not be uniform. Use of inhibitors is quite effective in some cases, even with small quantity. Tables, graphs, 9 references. —INCO. 21013

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

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(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

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Topic of the Month

Location of the Half Cell in Measuring Potential of Structures to Earth

By KENNETH G. COMPTON*

Abstract

Significance of errors introduced into the circuits used to measure ground potentials is discussed. Effect of resistances related to distance from the structure being examined is explained. If the engineer is aware of the probable errors in his method he can accommodate his design to them. 4.5.3

Introduction

THERE HAS BEEN a great deal of discussion in corrosion meetings about the location of the half cell in making measurements of the potential of structures to earth. Some misconceptions have developed due to a lack of understanding of the fundamentals of electrochemical measurements. In one area the term "raised earth" potentials is used, while in another the phrase is "remote earth." It would be well to determine here the significance of such terms.

The experienced electrochemist is aware of the necessity of eliminating as much IR drop as possible from his measurement of the potential of a metal surface in an electrolyte to a reference electrode. For this reason he uses either a capillary tip and salt bridge to his half cell or some bridge circuit which effectively eliminates the IR drop components. The capillary tip explores the potential immediately under or adjacent to it. In this way variations in potential over the surface can be observed.

If the tip is moved away from the specimen perpendicular to its surface, the measurement tends to be the average of an area under a cone of approximately 120 degrees, provided negligible current is flowing in the electrolyte. If current is present, the measurement is the resultant vector sum of the IR drop components and the interfacial potentials over the area.

In the laboratory, the effect of the IR drop may be eliminated effectively by using the bridge circuit described by Schwerdtfeger[1] and Holler[2] or by the Pearson[3,4] null bridge cricuit. The distance the tip of the half cell is away from the surface will determine the area which is averaged. Even here, one must be mindful of the screening effect of the half cell or capillary tip if placed close to the structure surface when current is flowing.

In the field, the techniques of the laboratory usually are not applicable. In the absence of interfering structures or stray currents, the null bridge of Pearson may be used with a considerable degree of success. It must be kept in mind, though, that the near electrode should be as close to the structure as possible to narrow down the area of the structure being explored.

The other bridge circuit is not applicable to practical field work. A study of the circuits of the above authors and the uses to which they have been put, is recommended so that the reader will understand how these workers arrived at their criteria for cathodic protection.

Pope[5] made a study of the potentials between a pair of half cells in contact with earth at different spots in an area when there was no stray current. He found variations in potential between the half cells of as much as 26 millivolts, depending upon where the cells were placed and upon whether the earth was freshly dampened with tap or salt water. Similarly the author reported variations of 35 millivolts in another area of no stray current. These and other measurements indicate a possible error of approximately 40 millivolts that is independent of other factors related to the location of the half cell. These errors are due to variability of the liquid junction potentials encountered in measurements through an electrolyte as complex as damp earth.

The concepts of "remote earth" and "raised earth potential" arose in the minds of electrical engineers to whom "ground" is a fixed thing or reference. In their circuitry, they think of the earth as a metallic structure to which they may attach their wires for the purpose of grounding as in a radio chassis. It was natural for them, when they encountered stray currents in the earth near metallic structures to drive a ground rod in the earth at a considerable distance from these structures to get away from the influence of the local stray currents. They thought of the earth as a fixed thing to which one could attach wires for reference purposes. When this "remote earth" was used as a reference in making corrosion studies it merely indicated the resultant vector sum of all the potentials between the remote ground rod and the structure. This included the interface potential of the particular ground rod and earth, and the averaging effect over a large area of the structure.

Similarly in their minds when a current was applied to a structure, buried in the ground, the combination of the polarization produced at the structure-electrolyte interface and IR drops did not cause a change of the structure potential but the earth was "raised" above the structure potential.

Other workers in the field of corrosion have resorted to an arbitrary placement of their reference, whether it be an iron stake or a half cell, at some distance such as 300 feet from the structure. Cathodic protection was assumed to be achieved if the potential of structure to reference was moved 300 millivolts negative or to —.85 volts on the copper sulfate scale (in the case of a steel structure). It is obvious that IR drop is neglected in this case.

Some of the utilities people have placed their reference electrode in manholes which in some cases tend to have insulating walls so that the potential of the structure in the subway, may not influence the reading. Errors due to IR drop would apply in this case whether the walls where insulating or not.

Telephone and electric power companies frequently make duct surveys in which the reference electrode is pulled through a vacant duct in a subway. While this method has the advantage of measuring a potential at close successive

* Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

intervals of distance, in some cases the resistance between the reference electrode and a particular cable may be so high that the potential indicated at that spot may not be that of the area of the cable adjacent to it.

In the absence of current in the earth, the location of the half cell is unimportant except for the angle of observation. If one wishes to see differences in potential over short intervals of length of the structure one should bring the half cell as close as possible. In the presence of current in the earth, the location of the half cell becomes very important. It should be as close to the structure as possible, to reduce IR drop errors. If one were to measure the potential of a half cell to structure at increasing intervals from a position over the structure out to the ground bed, one might obtain results similar to that obtained by the author in a 3,000 ohm-centimeter soil. The distance from a 300-foot length of buried cable was 300 feet. The potential applied between the cable and the anodes was 12 volts with a current to the 300-foot segment of cable of 135 milliamperes. The results are shown in Table 1.

TABLE 1

Location of Half Cell	Potential of Cable to Half Cell
Over the Cable	.90
10′	1.30
20′	1.60
30′	1.90
40′	2.10
80′	2.80
150′	3.70
220′	5.40

In this same experiment, a measurement was made at the bottom of a well so that the half cell was within 2 or 3 inches of the cable. This showed the structure-to-half cell potential was —.68 volts, and that with the Pearson Null Bridge it was —.52 volts. The potential without cathodic protection was —.33 volts. These measurements illustrate the magnitude of error which may result from placement of the half cell at any significant distance from the structure. The error due to IR drop will increase as the resistivity of the soil increases and as the current required by the structure increases. Where the half cell cannot be placed close to the structure an approximation of the resistance between the half cell location and the structure may be determined from $\Delta E/\Delta I$, and a suitable correction to the structure to half cell reading may be made. This method was described by Logan and Pearson.[4] While this is not very accurate, it tends to minimize the error.

The ideal location for the half cell may not be achieved in many situations, but an awareness of the probable error and the application of good judgment on the part of the corrosion engineer when adjusting his cathodic protection system will lead to adequate mitigation of corrosion without excessive waste of current. Any corrosion engineer who uses a purely arbitrary or indiscriminate location for his half cell will be introducing possible errors of unknown and oftentimes large magnitude.

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Any discussion of this article not published above will appear in December, 1961 issue.

Technical Papers on Corrosion Welcomed

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Corrosion Problems in a Sinter Plant Exhaust Gas System*

By R. J. SCHMITT

Abstract

Corrosion that occurred in the exhaust-gas system of a large sinter plant used for agglomerating iron-ore fines is described. Corrosion of the carbon-steel exhaust-gas system was found to be caused by condensation of sulfurous acid, sulfuric acid, and hydrochloric acid from the exhaust gases. The following possible methods of minimizing future corrosion in exhaust-gas systems are described: maintaining metal-surface temperatures above the acid dew-point, insulating equipment exposed to the weather, and the use of protective coatings. The electrical-resistance testing method and corrosion-specimen test for measuring corrosion rate and the ultrasonic testing method for measuring metal thickness were utilized in resolving the problem and are outlined in the discussion. 4.2.3

Introduction

ONE OF THE more important pieces of equipment being used by the steel industry is the sintering machine for agglomerating iron-ore fines. Corrosion of the large sinter-plant exhaust-gas systems that are used to remove combustion products caused by the sintering operation has resulted in high maintenance and replacement costs for the equipment, and in decreased production.

In an effort to resolve this serious sinter-plant corrosion problem, the United States Steel Corporation's Applied Research Laboratory initiated a four-phase testing program to determine: (1) the extent of corrosion, (2) the factors influencing corrosion, (3) the rate of corrosion, and (4) methods of eliminating corrosion. This discussion will review the testing program, with special emphasis on the methods used in resolving the problem, and will also present a brief description of the sintering process.

Sinter-Plant Operation

The function of the sinter plant is to agglomerate finely divided ores and flue dust into a more acceptable product for charging into the blast furnace. The feed to the sinter machine can contain fine ore and flue dust, and fuel materials such as pulverized coal, coke breeze, and coke-quenching-pit cleanings in varying amounts that will depend upon the mix desired. In the production of self-fluxing sinter, limestone or dolomite fines are added to the sinter mix. Calculated amounts of sinter fines and water are added to maintain the porosity of the sintering bed.

The above-mentioned materials are mixed in a revolving-drum or disc-type mill and then continuously fed onto the moving sinter-grate. The grate, as shown in Figure 1, then passes under an ignition furnace, which consists of a burner extending the width of the machine. Normally, natural gas with forced air is used for ignition; however, other fuels such as coke-oven gas and fuel oil can be used.

After passing under the furnace, the grate travels over a series of windlegs and air is drawn through the sintering bed and into the windlegs by a centrifugal fan. Ignition of the sintering bed occurs at the surface, and as the grate moves over the windlegs the burning zone progresses downward through the bed until it reaches the grate bars. When the bed is burned through, the sinter is dropped onto a discharge chute, then is cooled and transported to the blast furnaces.

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About the Author

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The exhaust gases exit through the windlegs and pass into the large plenum chamber where the initial collection of dust particles begins. These gases then pass through the plenum chamber into an electrostatic precipitator where the smaller dust particles are removed. A portion of the plenum chamber is enclosed in a building and is protected from the weather, Figure 1. After leaving the precipitator, the exhaust gases pass through the fan into the stack and are finally vented to the atmosphere. The exhaust-gas systems are constructed of carbon steel, and the severe corrosion of these extensive systems is the subject of the present discussion.

Extent of Corrosion

At one of the U. S. Steel Corporation's sinter plants, severe corrosion of the carbon-steel exhaust-gas chamber and electrostatic precipitator occurred during the first 18 months of service. A survey of the reduction of metal thickness was made by use of the ultrasonic thickness gage, to determine the extent of damage that occurred throughout the entire exhaust-gas system.

The ultrasonic thickness gage is an instrument for the nondestructive measurement of an unknown wall-thickness from one side. In this instrument, the principle of ultrasonic resonance in measuring thickness is used. Figure 2 shows the ultrasonic thickness gage and its method of application.

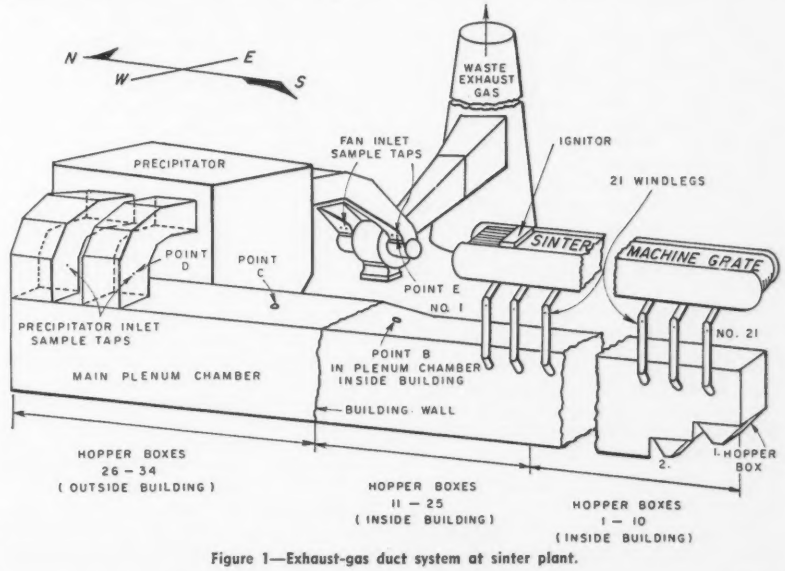

Figure 1—Exhaust-gas duct system at sinter plant.

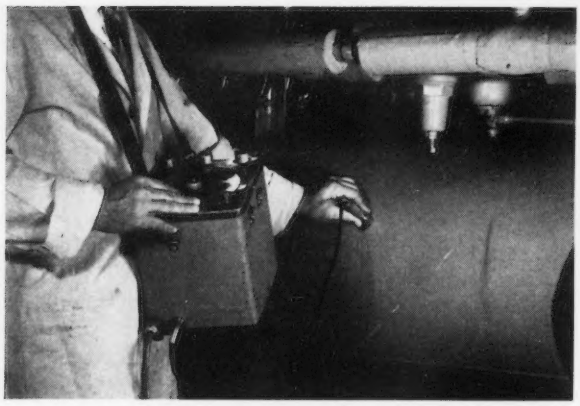

Figure 2—Ultrasonic thickness gauge and method of application. Approximately 1/10th actual size.

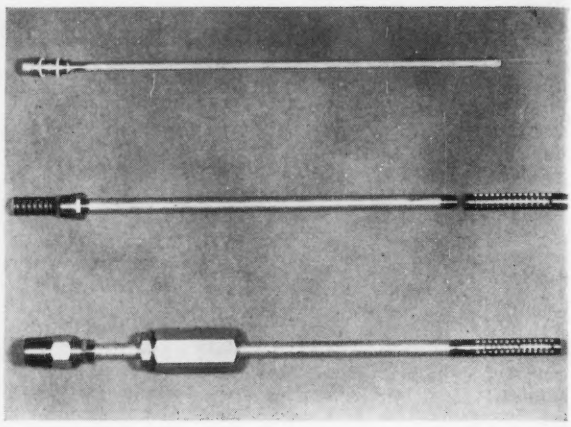

Figure 3—Electrical-resistance probe. Approximately 0.06 actual size.

The results of the survey are shown in Table 1 and are described below.

Windlegs

Table 1 shows that about a 37 percent reduction in metal thickness occurred on windlegs No. 1 through 15 and a reduction of about 17 percent on windlegs No. 16 through 21. The windlegs are numbered 1 through 21, from the cold to the hot end of the sinter bed.

Plenum Chamber

An average reduction in metal thickness of about 6 percent occurred on the main plenum chamber which is inside the building and which corresponds to the section of the plenum chamber above hopper boxes No. 1 through 10, as shown in Figure 1. A somewhat higher reduction in metal thickness of 17 percent occurred on the section of the plenum chamber inside the building; this section corresponds to the section above hopper boxes No. 11 through 25. For the remaining section of the plenum chamber, which is outside the building (hopper boxes 26 through 34), a still higher reduction of about 29 percent was recorded.

Precipitator

Visual examination of the internals of the precipitator revealed severe corrosion damage to the support frames, collection plates, rappers, and other related components. Because the internals of the precipitator were severely corroded, the unit became inoperative.

Thickness measurements of the insulated north wall of the unit, which was readily accessible for measuring, revealed a 14 percent reduction in thickness. The severe corrosion that occurred on the internals of the unit was not reflected in the rather moderate loss in metal thickness of the north wall of the precipitator.

Duct Work From Precipitator to Fan

A reduction in metal thickness of about 20 percent occurred on the duct in the area from the precipitator to the fan.

Stack

Thickness measurements were made at various elevations on the carbon-steel stack, which is 150 feet high and 17 feet in diameter and is covered internally with a 3-inch-thick Portland cement lining. The results of the measurements revealed negligible metal loss throughout the entire shell of the stack. Visual examination of the inside of the stack revealed that the cement lining was very hard and uncracked. The good condition of the steel shell of the stack can therefore be attributed to the excellent protection afforded by the lining.

TABLE 1—Results of Ultrasonic Thickness Measurements on Entire Exhaust-Gas System

Location	Original Thickness, inch	Average Reduction in Metal Thickness, inch	Percent Reduction	Average Corrosion Rate,** mils per year
Windlegs				
(1-15)	0.50	0.187	37	125
(16-21)	0.50	0.084	17	56
Plenum Chamber				
Inside Building, Hopper Boxes (1-10)	0.375	0.024	6	16
Inside Building, Hopper Boxes (11-25)	0.375	0.063	17	42
Outside Building, Hopper Boxes (26-34)	0.375	0.110	29	73
Precipitator				
North Wall	0.250	0.034	14	23
Duct Work From **Precipitator to Fan**	0.375	0.074	20	49
Stack	0.250	*	..	...

* Negligible metal loss.
** Based on 18 months operation.

Factors Influencing Corrosion

Corrosion that occurs in sinter-plant exhaust-gas systems is associated primarily with the condensation of the moisture and acidic gases present in the exhaust gas. The pulverized coal and coke-quenching-pit cleanings used as fuel material in the sinter mix, as well as the coke-oven gas used to ignite the sinter mix, contain large amounts of sulfur and chlorine compounds. At combustion temperatures, the sulfur compounds dissociate and/or oxidize to form sulfur dioxide (SO_2) and sulfur trioxide (SO_3). As the waste gases pass through the exhaust system, the temperatures decrease. When the temperature is sufficiently low, SO_3 combines with water to form sulfuric acid, which condenses on the metal surface and causes severe corrosion of the steel exhaust system. At high temperatures, the chlorine compounds also dissociate, so that at low temperatures hydrochloric acid is formed on the metal surface with resulting severe corrosion.

TABLE 2—Average Acid and Moisture Concentrations in Exhaust Gas

Constituent	Average Concentration g/scf	Average Concentration % Volume
Regular Sinter		
Cl	0.0056	0.0120
SO_4	0.0389	0.0322
H_2O	.....	25.0
Self-Fluxing Sinter		
Cl	0.0022	0.0047
SO_3	0.0021	0.0017
SO_4	0.0052	0.0043
H_2O	.....	15.0

The corrosion of steel exhaust-gas systems is markedly influenced by temperature. Also, the severity of the corrosion can vary; the extent of variation will depend upon whether the exhaust-gas temperature is below the acid dew-point or water dew-point. Miller,[1] among others, has found that small amounts of SO_3 will raise the acid dew-point (the temperature at which the acid

constituents condense) of the gases to a marked degree. The water dew-point usually varies between 90 to 130 F, but Miller's work showed that the addition of only 0.001 percent of SO_3 will increase the dew-point from the water dew-point of about 100 F to about 300 F. However, further increases of SO_3 in the gases only raises the dew-point by a small amount. The presence of SO_2 in the gases, unlike the presence of SO_3, does not affect the dew-point of the gases. However, SO_2 will appear as sulfurous acid when the water dew-point is reached. Also, HCl formed in the combustion gases will not deposit in the liquid phase until temperatures slightly above the water dew-point are reached.[2,3] Concentration of HCl rapidly increases below the water dew-point. Therefore, the exhaust-gas temperature will determine whether corrosion can be primarily the result of sulfuric acid or, if temperatures are sufficiently low, the corrosion can be aggravated by the presence of hydrochloric acid and/or sulfurous acid. The most severe corrosion occurs during the latter condition.

To determine the acid dew-point of the sinter-plant exhaust gas, the concentration of $SO_3^=$ and $SO_4^=$ and Cl^- in the exhaust gas was measured. Table 2 gives the average acid and moisture concentrations of the gas both when regular sinter (nondolomitic) was being produced and when self-fluxing sinter was being produced. According to information developed by Kear,[4] the acid dew-points of exhaust gases containing the acid and moisture concentrations shown in Table 2 should range from 290 F to 335 F.

Table 2 shows that during periods when self-fluxing sinter was being produced, lower acid concentrations were recorded. These lower acid concentrations were probably due to the neutralizing effect of the dolomite. Earlier work done in the utilities field has shown that the addition of small amounts of dolomite to coal will reduce the amount of sulfur trioxide in a boiler system.[3,5]

Temperature measurements made at several locations throughout the exhaust-gas system revealed many variations in temperature that would affect the condensation rate of the acids causing corrosion and would explain the wide variation in corrosion found throughout the system. The results of the temperature survey, Table 3, show that a steady decrease in gas temperature occurs between the entrance to the plenum chamber and the fan, with a total temperature drop across the system of about 40 F. Although not shown in Table 3, the gas temperature may rise to as high as 500 F in the plenum chamber for a period of 5 to 10 minutes following a shutdown of the sintering machine, whereas it may drop to as low as 153 F at the fan while the machine is in operation.

Also given in Table 3 are the results of metal-surface-temperature measurements. This table shows that temperatures at the precipitator and fan averaged 140 F and 100 F, respectively. The walls of the precipitator are insulated; therefore, higher metal-surface temperatures would be expected. Even when the plant was inoperative for periods of 16 hours, the temperature of the precipitator walls did not drop appreciably, because the insulation minimized the heat loss. These higher surface temperatures, caused by insulation, resulted in less condensation on the walls and, therefore, less corrosion.

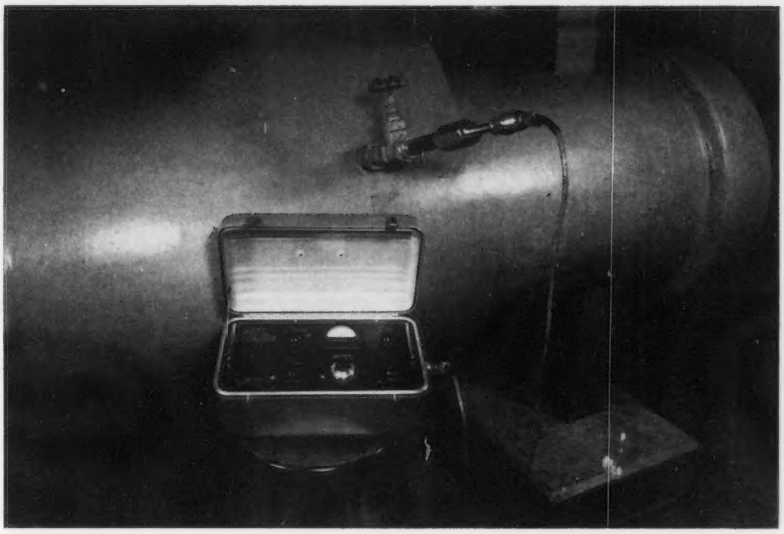

Figure 4—Portable electrical-resistance meter and typical installation. Approximately 0.06 actual size.

TABLE 3—Temperature Survey of Exhaust Gas and of Duct-Work Surface*

Exhaust Gas	Temperature, F		
	Avg.	Max.	Min.
Plenum (from ignition section to inside wall of building)	250	354	175
Plenum (from outside wall of building to precipitator inlet)	240	312	158
Inlet to precipitator	230	312	165
Inlet to fan	210	297	153
Duct-Work Surface			
Southeast wall of plenum outside building (protected)	145	165	135
Northwest wall of plenum outside building (unprotected)	90	110	85
Wall of precipitator	140	...	...
Wall of fan	100	108	90

* Ambient temperature of 75 to 90 F during tests.

TABLE 4—Average Corrosion Rates as Determined by the Electrical-Resistance Method

Probe Location	Length of Test, days	Average Corrosion Rate, mils per year
Windlegs		
Number 7	1.8	267*
Number 9	0.8	324*
Number 15	1.0	300*
Plenum Chamber Inside Building	7	61
Plenum Chamber Outside Building	20	50
Inlet to Precipitator	24	51

* The high corrosion rates were due partly to corrosion, but mainly to abrasion from the large amount of sinter dust passing around the probes.

TABLE 5—Corrosion Rates of Metal Exposed in Sinter-Plant Exhaust-Gas System

Material	Exposure Period, Days	Corrosion Rate, mils per year	
		Location A*	Location B**
Carbon steel	78	127	159
USS Cor-Ten steel	78	109	159
AISI Type 410 stainless steel	78	72	126
AISI Type 430 stainless steel	78	83	124
AISI Type 304 stainless steel	78	102	102
AISI Type 316 stainless steel	78	76	108
Inconel	78	140	191
Titanium	78	9	45
Carbon steel	160	48	...
USS Cor-Ten steel	160	35	...
USS Vitrenamel steel	160	28	...
Aluminum (3003)	160	84	...

* Top of plenum chamber inside building.
** Top of plenum chamber outside building.

Rate of Corrosion

Electrical-resistance probes were utilized in the investigation to determine the rate of corrosion occurring in the exhaust-gas system and to correlate corrosion with operations.

The electrical-resistance method is a direct means of measuring corrosion continuously and is used to follow the progress of corrosion in operating equipment. A special probe and meter are utilized in conducting these measurements. Figure 3 shows an electrical-resistance probe, and Figure 4 shows a portable meter and typical installation. When measurements are made, the probe containing an element of the material to be tested is placed in the system under study and is then electrically connected to the meter. The meter measures the change in electrical resistance of the probe ele-

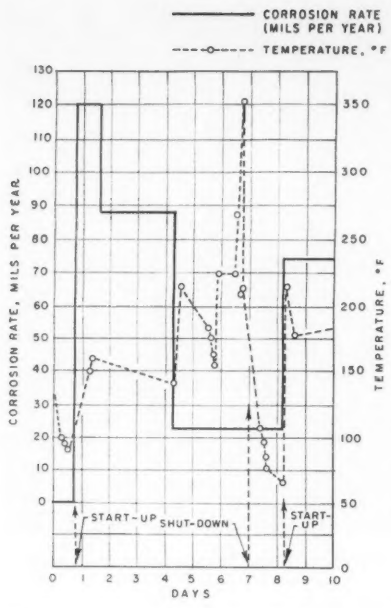

Figure 5—Corrosion-temperature profile for plenum chamber outside building.

TABLE 6—Appearance of Protective Organic Coatings Exposed in Sinter-Plant Exhaust-Gas System (Length of Exposure, 78 Days)

Organic Coating*	Rating	Appearance
Location A (Organic coatings applied to wire-brushed carbon-steel panels.)		
Coal Tar Epoxy	Poor	Considerable failure due to hardening and cracking of coating.
Baked Phenolic	Poor	Complete failure.
Modified Silicone	Poor	Considerable attack in spots, with subsequent undercutting by rust.
Epoxy	Poor	Some failure on corners; rusting on edges.
Coal Tar	Poor	Coating badly deteriorated by heat; slight attack in spots on metal.
Location B (Organic coatings applied to sand-blasted carbon-steel panels.		
Coal Tar Epoxy	Good	Virtually intact.
Baked Phenolic	Fair	Intact except for slight failure at edges.
Modified Silicone Alkyd	Fair	Intact except for slight failure at edges.
Epoxy	Poor	Complete failure; brittle coating; severe undercutting by rust.
Coal Tar	Poor	Coating partially deteriorated by heat; some spots showing thermal attack on base metal.

ment as the cross-sectional area of the element is reduced by corrosion. The amount of corrosion can then be read directly from the meter in microinches penetration of the probe element.

Measurements were taken on electrical-resistance probes installed at Points A, B, C, D, and E, as illustrated in Figure 1. The average results of those measurements are shown in Table 4.

Windlegs

Table 4 shows that very high corrosion rates of 267, 324, and 300 mils per year (mpy) were recorded for windlegs No. 7, 9, and 15, respectively. Considerable sinter dust passes through the windlegs; therefore, the high corrosion rates recorded for them are due mainly to abrasion.

Although not shown in Table 3 the wall temperatures of the windlegs varied from below 200 F at the cold end of the machine (No. 1-14) to above 300 F at the hot end of the machine (No. 15-21). Therefore, the location of the windleg determines whether the attack on the windleg walls will be either primarily acid corrosion or primarily abrasion, or a combination of both.

Plenum Chamber

As shown in Table 4 corrosion rates of 50 and 61 mpy were recorded on the electrical-resistance probes located in the plenum chamber.

In an effort to correlate corrosion with operations, a probe was installed in the plenum chamber for 10 days. Corrosion rates recorded on the probe are shown in Figure 5, where it is evident that the maximum corrosion rate, which averaged between 80 to 120 mpy, was recorded during start-up periods. During start-up periods, the temperature of the walls of the duct work is lower than the temperature of the exhaust gas, with consequent maximum sidewall condensation. After the operating temperatures returned to normal, the corrosion rate decreased markedly; this rate, which varied from 20 to 85 mils per year, was determined by the gas temperature developed during the sintering operations.

Duct Work to Precipitator

A corrosion rate of 51 mils per year was recorded on the probe installed in the inlet to the precipitator. This rate is similar to that obtained for the plenum chamber outside the building.

In general, the data obtained from the electrical-resistance probes are in agreement with the thickness measurements obtained with the ultrasonic thickness gage.

TABLE 7—Appearance of Protective Cement Coatings Exposed in Sinter-Plant Exhaust-Gas System

Cement Coating	Thickness of Coating, Inches	Exposure Period, Days	Coating Rating	Appearance
Location A				
Refractory Cement Type A	3/8	78	Fair	Very little acid attack; small surface hai cracks; bond broken between cement an steel back-up panel.
Refractory Cement Type B	3/8	78	Fair	Slight acid attack; two transverse crack across panel extending the depth of th cement coating; bond broken between ce ment and steel back-up panel.
Location B				
Refractory Cement Type A	3/8	30*	Fair	Small surface hair cracks; bond broken be tween cement and steel back-up panel.
Refractory Cement Type B	3/8	30*	Fair	Four transverse cracks across panel extend ing the depth of the cement coating; bond broken between cement and steel back-up panel.
**Lumnite (Haydite Aggregate)	2½	78	Good	Slight acid attack; no cracks.

* Panels destroyed after 45-day exposure period as a result of corrosion failure of the bolts that secured the panels to the test racks. The results presented here were obtained from a plant inspection of the panels after 30 days of exposure.

** Gunite applied; other coatings were applied with a trowel.

Methods of Reducing Corrosion

To determine suitable materials of construction and protective coatings for use in sinter-plant exhaust-gas systems, corrosion-test panels were installed in the equipment. Exposed in the test were panels of structural carbon steel, USS Cor-Ten high-strength low-alloy steel, USS Vitrenamel steel, aluminum (3003), AISI Types 410, 430, 304, and 316 stainless steels, Inconel, and titanium. Carbon-steel panels coated with the following organic protective materials were also exposed on the racks: coal-tar epoxy, modified silicone alkyd, phenolic resin, and coal tar; also exposed were three refractory cements, including Lumnite acid-resisting cement (with Haydite as the aggregate). The test panels were exposed at two locations in the plenum chamber: (A) the top of the plenum chamber inside the building, and (B) the top of the plenum chamber outside the building.

The results of the test-panel evaluations are shown in Tables 5 through 7. The data in Table 5 indicate that all the metals tested were severely attacked. Titanium was the most resistant metal tested, exhibiting a corrosion rate of 9 mils per year in the plenum chamber inside the building and 45 mils per year in the plenum chamber outside the building. Table 5 shows that the corrosion rates for carbon steel and USS Cor-Ten steel decreased with time of exposure.

Table 6 shows that the coal tar epoxy coating exposed outside the building (location B), was the only organic coating that was rated as good. All the organic coatings exposed inside the building (location A) failed because of higher temperatures that prevail in the plenum chamber inside the building. The investigation showed that the coal tar epoxy coating would be a suitable protective material if temperatures were kept below 325 F at all times.

The results for the refractory-cement coatings, Table 7, indicate that they give the best resistance to the corrosive ex-

haust-gas condensate. However, only the Lumnite-cement coating showed no evidence of cracking. This coating's superior resistance to cracking may have been due to its thickness and to the method of application. Because this cement has excellent resistance to high-temperature attack, a test panel was placed only on the rack exposed in the plenum chamber outside the building, to determine its resistance to acid attack.

The corrosion-testing program is being continued to determine the resistance of additional organic protective coatings and refractory cements.

Based on the results of the sinter-plant corrosion investigation, the following methods are suggested for reducing or eliminating corrosion in sinter-plant exhaust-gas systems:

1. Insulate exposed walls to maintain maximum metal-surface temperature, which will minimize acid condensation.

2. Preheat exhaust-system walls, utilizing sulfur-free fuel or steam tracing to reduce condensation during start-up; this will reduce the severe corrosion that occurs on start-up.

3. Utilize auxiliary burners to raise the temperature of the exhaust gas above the acid dew-point during operations.

4. Coat the inner walls of exhaust-gas systems with Lumnite acid-resisting cement to prevent corrosion.

Before being applied in a particular sinter plant, each of the above suggested methods for reducing or eliminating corrosion should be studied from a standpoint of economics.

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Any discussion of this article not published above will appear in December, 1961 issue.

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Effect of Solution pH on the Mechanism Of Stress Corrosion Cracking Of a Martensitic Stainless Steel*

By H. J. BHATT and E. H. PHELPS

Abstract

Experiments were conducted to determine the effect of solution pH on the stress corrosion cracking of a specially alloyed martensitic stainless steel, USS 12 MoV stainless, in a 3 percent sodium chloride solution saturated with oxygen. The time for stress corrosion failure was shortest at pH 1 and increased gradually as the pH was increased from 3 to 11. Stress corrosion cracking did not occur when the pH was 11.5 or higher. Anodic polarization caused relatively rapid cracking at pH 1, 6.5, and 12.5, and the mechanism of cracking was corrosion along an active path through the steel. Cathodic polarization at relatively high current densities also caused cracking at pH 1, 6.5, and 12.5, but under these conditions the mechanism was hydrogen embrittlement. Without applied current at pH 6.5, the mechanism is corrosion along an active path, but at pH 1, either this mechanism or hydrogen embrittlement could cause cracking.

3.5.8, 3.4.7, 6.2.5

Introduction

A PREVIOUS paper co-authored by one of the present authors gave the results of an extensive series of atmospheric and laboratory stress corrosion tests on alloy and stainless steels intended for use in high-speed aircraft and missiles.[1] These results showed that very high strength steels hardened by heat treatment are, like many non-ferrous alloys used in conventional aircraft, susceptible to stress corrosion cracking under certain conditions. The use of protective coatings that are anodic to steel were found to be very effective in preventing stress corrosion cracking. Also, austenitic stainless steels hardened to very high strength levels by cold working were much more resistant than steels hardened by heat treatments. The latter types of steel were resistant to stress corrosion cracking when tempered at temperatures of 1100 F and above, but these treatments result in reduced strength.

One of the steels for which data were presented in the previous paper was a specially alloyed martensitic stainless steel, USS 12 MoV stainless. This steel exhibited a relatively short time to failure in the atmospheric stress corrosion tests, and also exhibited stress corrosion cracking in several laboratory solutions containing anions other than chloride. The results of anodic and cathodic polarization experiments in an aerated solution of 3 percent sodium chloride at room temperature indicated that with no current, with anodic polarization, and with cathodic polarization at relatively low current densities, the mechanism of cracking consisted of corrosion along an active path through the steel. With cathodic polarization at relatively high current densities, the mechanism of cracking consisted of hydrogen embrittlement.

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The present work deals with the effect of solution pH on the mechanism of stress corrosion cracking of 12 MoV stainless steel in 3 percent sodium chloride solution saturated with oxygen.

Experimental

Material

The chemical composition, heat treatment, and mechanical properties of the USS 12 MoV stainless steel used in this investigation are shown in Table 1.

Stress-Corrosion Tests

Bent-beam specimens were used in the stress corrosion tests. The specimens were 0.57-inch wide and 0.020-inch thick, and were cut to a length calculated from a relationship between (1) the strain in the outer fibers at the middle of the specimen, (2) the specimen length, (3) the specimen thickness, (4) the modulus of elasticity of the steel, and (5) the holder span.[1] In all the experiments, the stress level used was 75 percent of the yield strength. The specimens were ground on a 120-grit emery belt until all visible surface defects were removed, and were then degreased in trichloroethylene, washed in distilled water, and dried with acetone.

Bhatt Phelps

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The specimens were stressed by bending them and inserting them into polyvinylchloride holders. The span length of the holders was 4 inches. Electrical connections were made at one end of the stressed specimens to permit polarization with anodic or cathodic current, as desired. These connections were insulated from the solution with a wax coating.

Six specimens were used to determine the time to failure at each of the applied current densities and without applied current. The time to failure was taken as the time required for the specimen to separate into two pieces. One specimen was placed in each of six 2-liter beakers. As shown in Figure 1, each beaker contained a saturated calomel electrode for solution-potential measurements, an auxiliary platinum electrode for impressing anodic and cathodic current on the stressed specimen, and a tube for bubbling oxygen in the solution. Also shown in Figure 1 is the electrical arrangement used for impressing anodic or cathodic

TABLE 1—Chemical Composition, Weight Percent

Steel	Element, Weight Percent								
	C	Mn	P	S	Si	Ni	Cr	V	Mo
USS 12 MoV Stainless	0.26	0.56	0.026	0.025	0.30	0.75	12.36	0.29	1.02

Heat Treatment* and Mechanical Properties

Yield Strength, (0.2 percent offset), psi	Tensile Strength, psi	Elongation In 2 Inches, Percent
203,000	260,000	9.0

* Heat Treatment: Austenitized for 15 minutes at 1850 F, air cooled, continuously tempered at 800 F for 5 minutes, air cooled, tempered at 800 F for 4 hours, air cooled.

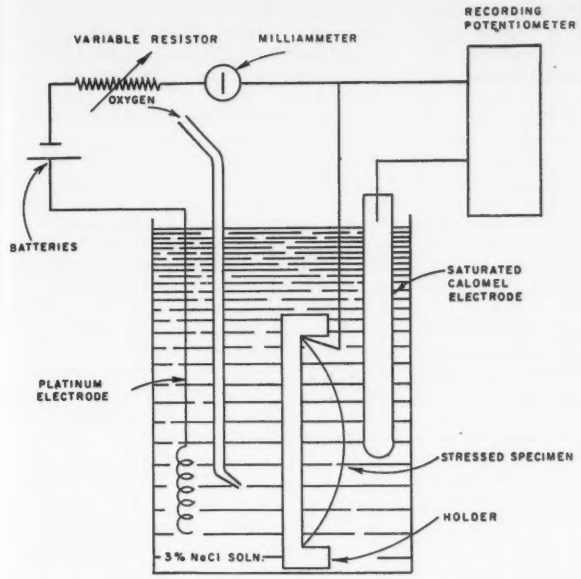

Figure 1—Arrangement for anodic or cathodic polarization.

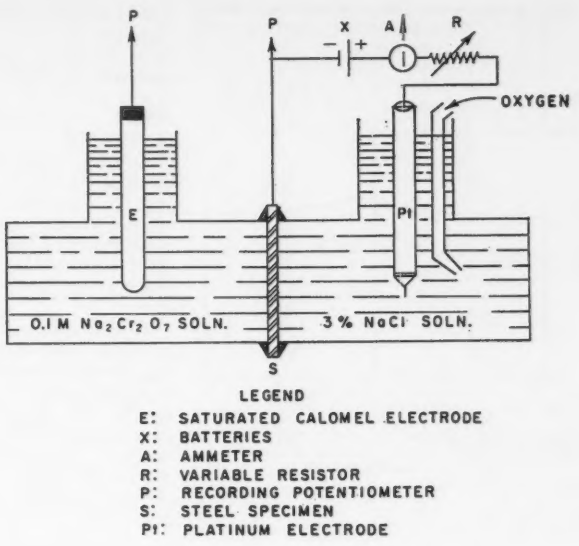

Figure 2—Electrochemical cell for hydrogen-diffusion studies.

current on the stressed specimens and for measuring the solution potential of the stressed specimens.

In each experiment to determine the effect of applied current, the stressed specimens and the platinum electrode in each of the six beakers were connected in series to insure the charging of the same amount of current on each specimen. The potential measurements were made with a 12-point, high-impedance potentiometer recorder. This instrument's range is 0 to 1000 millivolts and can be adjusted for a full-scale range of 200 millivolts.

The 3 percent sodium chloride solutions were adjusted to the desired pH by the addition of dilute hydrochloric acid or sodium hydroxide. These adjustments were made prior to the initiation of the experiments. No further adjustment of the pH was made during the experiments. The pH of the solutions initially adjusted to pH 1 or 12.5 did not change appreciably during the various experiments. The pH of the solutions initially in the neutral range, however, did increase during the longer polarization experiments. It is believed that the increase in pH which occurred in some of the experiments would not have an appreciable influence upon the interpretation of the results obtained because, as will be shown later, changes in pH in the neutral range (up to 11) have only a moderate influence upon time to failure. It is also recognized that polarization can produce a pH at the specimen surface which is substantially different from the bulk pH. These changes in pH could have been minimized by the use of buffered solutions. However, it was preferred not to use buffered solutions because the different amounts and possibly different types of buffer compounds required to obtain the desired pH values could have resulted in a change in the time to failure. The solutions were aerated with oxygen prior to and during the experiments. Except for this aeration, the solutions were not stirred. All tests were conducted at room temperature.

Hydrogen-Diffusion Tests

A method developed previously by Davis and Butler[2] was used to study the diffusion of hydrogen through the specimens. In this method, hydrogen that enters steel from a solution exposed to one surface is detected by potential measurement made on the opposite surface, which is exposed to a passivating solution. The potentiometer recorder used in the stress corrosion tests was also used in these experiments to record the change in solution potential on the side of the specimen exposed to the passivating solution.

The specimens of 12 MoV stainless used were flat, had an area of one square inch, and were not stressed in these tests. They were given the same surface-cleaning treatment as that used in stress corrosion tests. One side of each specimen was exposed to an oxygen-saturated solution of 3 percent sodium chloride, adjusted to different solution pH, as an electrolyte, while the other side of each specimen was exposed to a 0.1 M sodium dichromate solution as a passivating solution. Figure 2 shows a diagrammatic sketch of the construction and arrangement of the cell used in these tests. Each cell unit holds about 50 cc of solution.

A steel sample was affixed to the glass cell by beeswax seals. A solution of 0.1 M sodium dichromate was poured into one cell-unit. The steel surface was exposed to the sodium dichromate solution for at least 30 minutes, to obtain reproducible readings. The electrolyte was then added in the second cell-unit and the potential of the steel surface was recorded with reference to a saturated calomel electrode in the solution. So that the effect of cathodic charging could be determined, an external battery was used to make the steel specimen the cathode and the platinum electrode the anode.

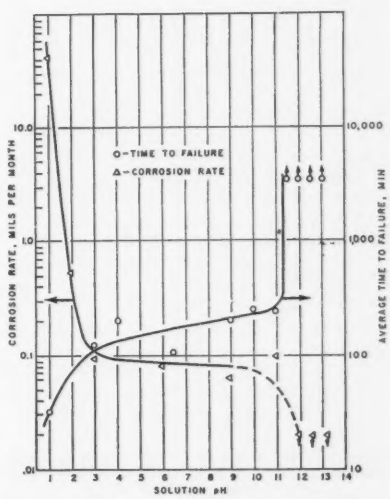

Figure 3—Effect of pH on time to failure and initial corrosion rate of USS 12 MoV stainless steel in oxygenated 3 percent NaCl solution.

Corrosion Tests

The effect of solution pH on the initial rate of corrosion in oxygen-saturated 3 percent sodium chloride solution was determined by exposing 1- by 2-inch specimens to solutions of different pH for 24 hours. The specimen preparation was the same as that used in the stress corrosion tests. The rate of corrosion in terms of average penetration in mils per month was calculated from weight-loss measurements.

Results and Discussion

Effect of pH on Corrosion and Stress-Corrosion Cracking

The effect of solution pH on corrosion and on stress corrosion cracking of 12 MoV stainless in 3 percent sodium chlo-

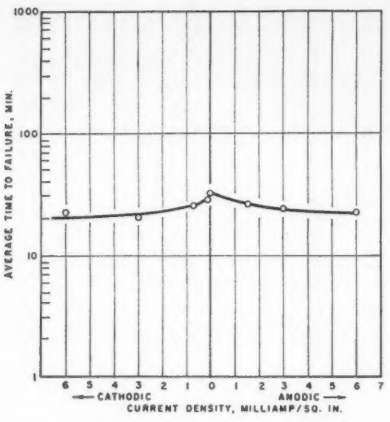

Figure 4—Effect of applied current on time to failure for USS 12 MoV stainless steel in oxygenated 3 percent NaCl solution at pH 1.

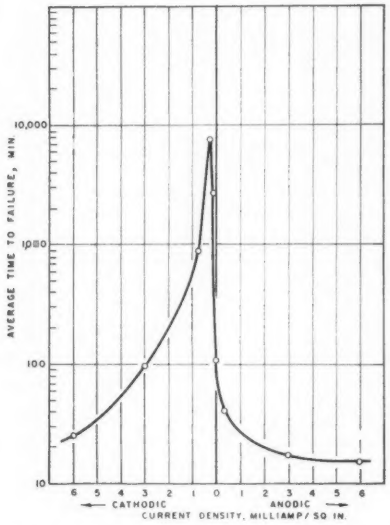

Figure 5—Effect of applied current on time to failure for USS 12 MoV stainless steel in oxygenated 3 percent NaCl solution at pH 6.5.

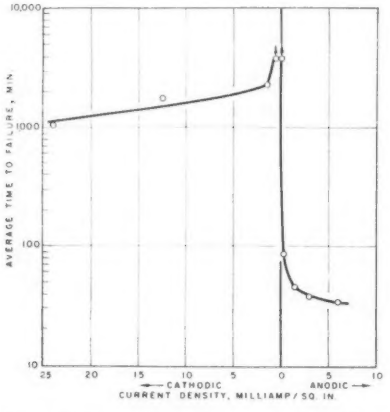

Figure 6—Effect of applied current on time to failure for USS 12 MoV stainless steel in oxygenated 3 percent NaCl solution at pH 12.5.

ride solution is shown in Figure 3. It is apparent that the time to failure gradually increases and the corrosion rate gradually decreases as the pH is increased in the pH range of from about 3 to 11. At pH greater than 11, stress corrosion cracking did not occur and the corrosion rates were negligible. On the other hand, the time to failure was sharply reduced and the corrosion rate was sharply increased at pH 1. At this pH, hydrogen evolution from the surface of the specimens was evident. Hydrogen evolution was not observed at pH 3 or above, however.

Thus it appears that at a low pH, both corrosion and stress corrosion cracking are associated with hydrogen evolution as the principal cathodic process. In the middle pH range (pH 3 to pH 11), oxygen is probably the principal reactant. At high pH (11.5 and above), both corrosion and stress corrosion cracking are prevented, probably by the formation of protective oxide or hydroxide films.

Effect of Anodic and Cathodic Polarization

The effect of anodic and cathodic polarization on the time to failure for 12 MoV stainless in 3 percent sodium chloride solutions with pH of 1, 6.5, and 12.5 is shown in Table 2 and in Figures 4, 5, and 6, respectively. These pH values were chosen for the polarization experiments because they represent the pH ranges wherein 12 MoV stainless exhibits markedly differing behavior; that is, hydrogen evolution, oxygen absorption, and inhibition.

Although neither type of polarization had a pronounced effect at pH 1, both anodic and cathodic polarization resulted in a general decrease in the time to failure, Figure 4. At pH 6.5, anodic polarization reduced the time to failure. With low cathodic-current densities, the time to failure was greatly extended, but at relatively high cathodic-current densities the time to failure became progressively shorter. These results are similar to those obtained previously with 12 MoV stainless in 3 percent sodium chloride solution saturated with air at pH 6.5.[1] At pH 12.5, failure did not occur without applied current, but failure did occur readily under conditions of anodic polarization. Failure did not occur with cathodic polarization at a low cathodic-current density, but did occur when higher current densities were applied.

The reproducibility of the experiments was generally good and in only a few instances was a large scatter in results for the six specimens obtained (see Table 2). Even when scatter was obtained, the number of specimens tested was sufficient to establish the general effects of anodic and cathodic polarization on the stress corrosion behavior of 12 MoV stainless. Polarization experiments with another heat of this steel and with this heat processed in a different manner have shown different times to failure. However, with these other materials the effects of polarization were generally the same as shown in this paper.

The purpose of the polarization experiments described above is to distinguish between two possible mechanisms

TABLE 2—Effect of Anodic and Cathodic Polarization on Cracking Time (12 MoV Stainless in 3 Percent NaCl Solutions)

Type of Charging	Current Density, ma/sq/in.	Cracking Time, Minutes						
		1	2	3	4	5	6	Average
Solution pH = 1								
Cathodic	6.0	35	8	25	18	36	11	22
Cathodic	3.0	21	30	17	20	27	9	21
Cathodic	0.75	15	15	15	60	45	10	25
Cathodic	0.137	21	27	25	18	34	44	28
None	0	38	45	20	28	35	25	32
Anodic	1.5	30	35	30	25	20	20	26
Anodic	3.0	17	26	21	20	45	19	24
Anodic	6.0	18	20	22	23	30	22	22
Solution pH = 6.5								
Cathodic	6.0	10	20	10	75	20	10	25
Cathodic	3.0	130	105	15	130	65	130	95
Cathodic	0.75	190	1185	1190	1185	1185	260	865
Cathodic	0.337	65	4200	18600	4200	2940	15900	7660
Cathodic	0.137	1500	4360	3420	1835	3000	1780	2650
None	0	75	80	135	100	75	155	105
Anodic	0.337	40	40	40	30	45	45	40
Anodic	3.0	18	19	18	15	15	15	17
Anodic	6.0	11	15	15	15	17	19	15
Solution pH = 12.5								
Cathodic	24.0	35	770	690	1560	2400	720	1030
Cathodic	12.0	1800	870	2700	15	1680	3540	1760
Cathodic	1.5	1140	3900*	3900*	4670	1020	3900*	2270
Cathodic	0.337	3900*	3900*	3900*	3900*	3900*	3900*	....
None	0	3900*	3900*	3900*	3900*	3900*	3900*	....
Anodic	0.337	50	240	50	50	50	70	85
Anodic	1.5	50	50	50	35	65	35	47
Anodic	3.0	35	35	65	35	35	30	39
Anodic	6.0	33	45	38	40	32	25	35

* No failure in time indicated.

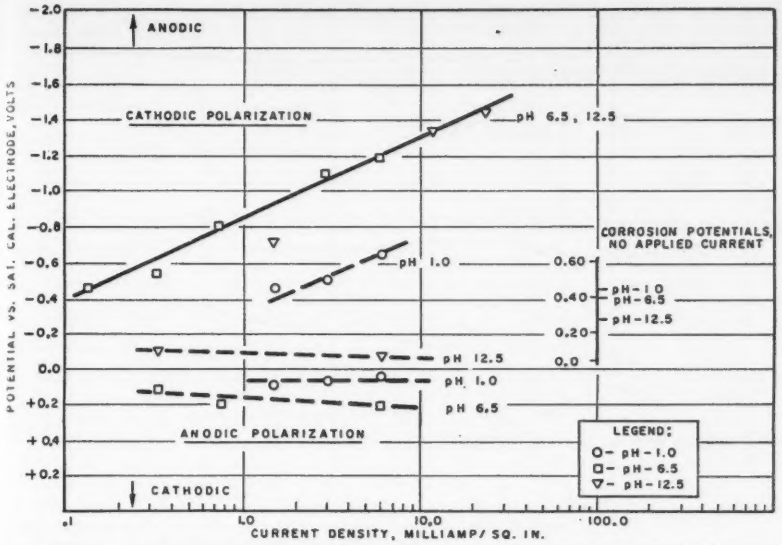

Figure 7—Effect of anodic and cathodic polarization for 12 MoV stainless steel in oxygenated 3 percent NaCl solutions of different pH.

TABLE 3—Hydrogen-Diffusion Tests, 12 MoV Stainless in Oxygenated 3 Percent NaCl Solution

Cathodic Current Density, ma/sq Inch	Time Lag, Minutes
Solution pH = 1.0	
None	1800
0.337	900
6.0	540
Solution pH = 6.5	
None	> 9900
0.337	4680
0.75	2100
1.5	1440
3.0	480
6.0	570
Solution pH = 12.5	
None	> 9900
0.337	> 14000
0.75	1320
1.5	960
3.0	990
6.0	900

of stress corrosion cracking in very high yield-strength steels; that is, localized corrosion along a continuous active path or general corrosion that generates hydrogen in the steel and causes hydrogen embrittlement. The interpretation of the effects of anodic and cathodic polarization on stress corrosion behavior in terms of these two mechanisms has been discussed previously.[1, 3]

At pH 1, 6.5, and 12.5, anodic polarization decreased the time to failure. This behavior is consistent with a mechanism consisting of corrosion along an active path because anodic current increases the amount of corrosion occurring on the specimens. It is not consistent with hydrogen embrittlement because if this mechanism prevailed, anodic current should decrease the amount of hydrogen generated and lengthen the time to failure. At pH 6.5, cathodic polarization at low current density greatly extended the time to failure. This behavior is again consistent with corrosion along an active path because cathodic current would be expected to suppress the corrosion reaction and to result in a longer time to failure. Cathodic polarization at relatively high current densities decreased the time to failure at pH 6.5 and 12.5. This behavior is consistent with the hydrogen-embrittlement mechanism because cathodic current would be expected to suppress corrosion and, at sufficiently high current density, generate hydrogen. At pH 1, the specimens evolved hydrogen without applied current, and cathodic polarization decreased the time to failure. This behavior, then, is also consistent with hydrogen embrittlement. However, because both cathodic and anodic polarization decreased the time to failure at this pH, it is not clear whether the mechanism of cracking without applied current is corrosion along an active path or hydrogen embrittlement.

Potential Measurements

The results of solution-potential measurements on the stressed specimens without applied current and with anodic and cathodic polarization are shown in Figure 7. The measurements shown were made just before cracking of the specimens occurred. The cathodic polarization at pH 6.5 and 12.5 was about the same and the Tafel-type curve obtained indicates that cathodic protection was obtained. The results at pH 1 suggest the same slope as that obtained at the higher pH values, but the curve is shifted so that appreciably higher cathodic-current densities were required to obtain a given potential at the lower pH. At all three pH values, the potentials remained relatively constant with anodic polarization as the anodic current density was increased. However, Figure 7 shows that anodic polarization at relatively low current density resulted in an appreciable change of potential from that observed without applied current.

The reversible hydrogen potential at one atmosphere pressure of hydrogen can be estimated to be —0.30 volts at pH 1, —0.63 volts at pH 6.5, and —0.98 volts at pH 12.5 (against the saturated calomel electrode). Because the observed corrosion potentials at pH 6.5 and 12.5, and the potentials with anodic polarization at pH 1, 6.5, and 12.5, were cathodic to their respective reversible hydrogen potentials, the evolution of hydrogen under these conditions would not be expected. This is additional evidence that stress corrosion under these conditions is not caused by hydrogen embrittlement. The corrosion potential at pH 1 was anodic to the reversible hydrogen electrode at this pH and hydrogen evolution was observed. However, as has been discussed earlier, this does not necessarily mean that the mechanism of cracking at pH 1 is hydrogen embrittlement.

In Figure 8, the potentials of the specimens before failure have been plotted against the average times to failure. Without applied current and with anodic polarization the results follow a generally consistent pattern in that the time to failure decreases as the potential becomes more cathodic. The result at pH 1 without applied current (see point on horizontal line in Figure 8), however, is not consistent with this pattern, and may indicate that the mechanism of failure here is hydrogen embrittlement. The result at pH 12.5 without applied current, where failure did not occur, also is not consistent with the other results.

On the basis of the previous discussion, the failures shown above the horizontal line in Figure 8 can be attributed to hydrogen embrittlement. In this region, the results at pH 6.5 show that the time to failure sharply decreases as the potential becomes more anodic; this also corresponds with an increase in cathodic-current density. The effect of potential on time to failure is not as pronounced at pH 12.5. It is interesting to note that at pH 6.5, the point corresponding to cathodic protection at 0.137 milliampere per square inch (point on the horizontal line at 2650 minutes, Figure 8) does not fall in line with the results at higher cathodic-current densities. Thus, it appears that partial cathodic protection and not hydrogen embrittlement is being obtained.

Terminal portions of representative potential—time curves for 12 MoV stainless without applied current in solutions of different pH are shown in Figure 9. At pH 3, 6.5, and 9, an anodic shift in the potential occurs prior to failure. The shift at pH 10 is much less pronounced. Generally, stress corrosion cracks could be observed on the specimens during the anodic shift. The occurrence of an anodic shift prior to cracking indicates that the cracking is caused by an electrochemical process. A shift in potential was not observed when cracking occurred at pH 1. This would be expected if cracking at this pH was caused by hydrogen embrittlement; however, it is also possible that the relatively rapid corrosion occurring at this pH would mask any electrochemical effects associated with cracking.

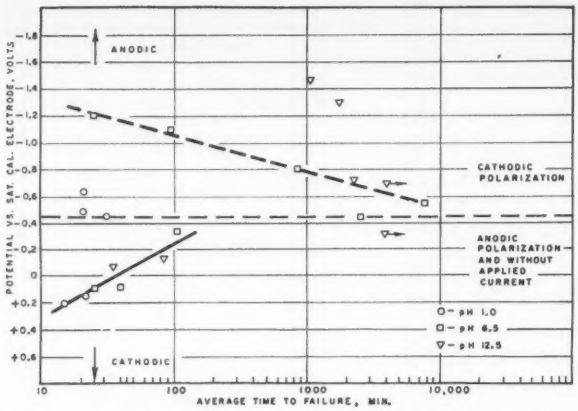

Figure 8—Effect of potential on time to failure for 12 MoV stainless steel in oxygenated 3 percent NaCl solutions of different pH.

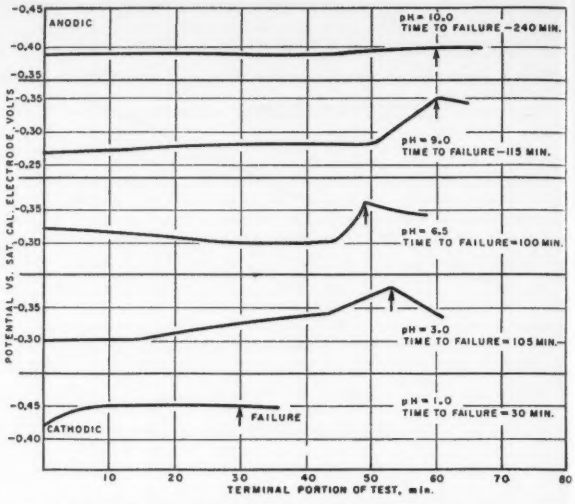
ANODIC
pH = 10.0 TIME TO FAILURE = 240 MIN.
pH = 9.0 TIME TO FAILURE = 115 MIN.
pH = 6.5 TIME TO FAILURE = 100 MIN.
pH = 3.0 TIME TO FAILURE = 105 MIN.
pH = 1.0 TIME TO FAILURE = 30 MIN.
FAILURE
CATHODIC
POTENTIAL VS. SAT. CAL. ELECTRODE, VOLTS
TERMINAL PORTION OF TEST, min.

Figure 9—Time-potential behavior of 12 MoV stainless steel in oxygenated 3 percent NaCl solutions of different pH.

Hydrogen-Diffusion Tests

The hydrogen-diffusion tests were conducted to determine whether hydrogen entered the steel in the experiments in which applied current was not used and in which cathodic charging was used (Table 3). Results obtained with anodic polarization were inconclusive because the specimens perforated, because of pitting, before a definite time lag.

Without applied current at pH 1, a potential change of the opposite surface occurred after 1800 minutes. Although this time is substantially longer than the time to failure (32 minutes), the occurrence of a potential change without applied current at pH 1 shows that hydrogen does enter and diffuse through the steel.

Hydrogen diffused through the specimens and caused a change in the solution potential of the opposite surface at all cathodic-current densities studied at pH 1 and 6.5. At pH 12.5, hydrogen diffused through the specimens at all cathodic-current densities except 0.337 milliampere per square inch; nor did cracking occur at this current density. The time lag generally became progressively shorter as the current density was increased. Without applied current at pH 6.5, there was no potential change of the opposite surface during 9900 minutes of test. This time is much longer than the time required for stress corrosion cracking to occur without applied current (105 min).

These results establish that hydrogen does enter and diffuse through 12 MoV stainless when this steel is cathodically polarized at current densities high enough to cause cracking, and are thus consistent with the stress corrosion tests which had indicated hydrogen embrittlement to be the cause of cracking under such conditions. The presence of a time lag without applied current at pH 1 establishes that hydrogen enters and diffuses through the steel, and that the mechanism of stress corrosion cracking could be hydrogen embrittlement under these conditions. The absence of a time lag without applied current at pH 6.5 is consistent with the results of the stress corrosion tests which had indicated that under these conditions hydrogen embrittlement is not the cause of cracking.

The observed times required for hydrogen to diffuse through the specimens in the diffusion tests are generally much longer than the observed times required for cracking to occur in the stress corrosion tests, Table 2; however, in two of the experiments, 0.337 milliampere per square inch at pH 6.5 and 1.5 milliampere per square inch at pH 12.5, the time lags were about one half of the time to failure. A significant difference in the two types of test which might account for the generally longer time lags is that both sides of the stressed specimens were exposed to the solution, whereas only one side of the diffusion specimens was exposed to the (corrosive) solution. Another possibly significant difference is that the stress corrosion specimens were stressed and the diffusion specimens were not. It is not known whether these differences would account for the disparity in the times observed in the two types of test, or whether the disparity in times is an indication that penetration of hydrogen into the thin surface layer of the stressed specimens could cause cracking under some conditions.

Summary

The results of this work on the effect of pH on stress corrosion cracking of 12 MoV stainless steel in 3 percent sodium chloride solution saturated with oxygen are summarized as follows.

1. At pH 1, stress corrosion cracking occurred relatively rapidly and hydrogen was evolved. In the pH range of from 3 to 11, somewhat longer times to failure were observed than at pH 1, the time to failure increased gradually as the pH was increased, and oxygen was considered to be the cathodic reactant. At pH 11.5 and above, corrosion and stress corrosion cracking were prevented, probably by the formation of protective oxide or hydroxide films.

2. Anodic polarization caused stress corrosion cracking at pH 1, 6.5, and 12.5. The mechanism of cracking under these conditions is corrosion along an active path.

3. Cathodic polarization at relatively high current densities caused cracking at pH 1, 6.5, and 12.5. The mechanism of cracking under these conditions is hydrogen embrittlement.

4. Cathodic polarization at relatively low current density extended the time to failure at pH 6.5.

5. Without applied current at pH 6.5, the mechanism of failure is corrosion along an active path.

6. Without applied current at pH 1, the mechanism of failure could be either hydrogen embrittlement or corrosion along an active path. Although not conclusive, evidence was obtained that cracking occurs by hydrogen embrittlement at this pH.

7. Hydrogen-diffusion experiments showed that with cathodic polarization at relatively high current densities at pH 1, 6.5, and 12.5, hydrogen does enter and diffuse through the steel. Also, without applied current at pH 1, hydrogen enters and diffuses through the steel.

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Any discussion of this article not published above will appear in December, 1961 issue.

A Technical Note

Hydrogen Service Failures of Welds With Insufficient Alloy Content*

By R. W. MANUEL*

Abstract

Low chromium-molybdenum alloys were used successfully in refineries to prevent hydrogen damage. Nevertheless welds failed under certain conditions after long exposure to hydrogen. A case history is discussed involving a weld in the channel of a reactor charge-effluent exchanger which saw service at 950 F and hydrogen partial pressure of 375 psi. It was found that the welds failing in service had inadequate chromium and molybdenum contents. 3.7.3, 8.4.3, 6.2.4

Introduction

THE EXTENSIVE use of catalytic reforming and hydrodesulfurization in the petroleum refining industry has greatly increased the amount of steel pressure equipment exposed to hydrogen-rich fluids at elevated temperatures. An insidious hazard in this equipment is the type of hydrogen damage to steel commonly known as high-temperature hydrogen attack. It involves irreversible embrittlement, decarburization, and microfissuring. One example of a costly failure was that of three catalytic reforming reactors reported along with considerable metallurgical detail in 1957 by Ciuffreda and Rowland.[1] Other failures have involved property loss and injuries to personnel.

Low Chromium-Molybdenum Alloys

In most of the hydrogen equipment in refineries, metal damage has been successfully avoided by using low chromium-molybdenum alloys adequate to withstand hydrogen at the fluid temperature or by keeping the metal temperature down with internal insulation. The selection of alloys for known temperature and hydrogen partial pressure conditions has generally been made on the basis of the Nelson curves first published in 1949.[2]

Some recent experiences in refineries have brought to light a special hazard deserving careful consideration wherever reliance is placed on chromium-molybdenum alloy steel for resistance to hydrogen attack. When alloy equipment is fabricated by welding, it is commonly specified that the weld metal analysis should be the same as the base metal. As the following case shows, however, errors leading to insufficient alloy content of welds can occur in fabrication. Such errors can go undetected when the equipment is placed in service and remain undetected until long exposure to hydrogen at elevated temperature results in failure.

★ Submitted for publication December 7, 1960.
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Figure 1—Cross-section of channel of exchanger. Note cracking in weld metal at right (light colored area) of specimen.

Weld Leak

In a catalytic reforming unit that had been in service for three years, a leak developed in a weld in the channel of a reactor charge/effluent exchanger. This weld had been exposed to fluid at a temperature of approximately 950 F and with a hydrogen partial pressure of approximately 375 psi. The plate material from which the channel was fabricated was 1¼ percent Cr, ½ percent Mo steel. It was found that the weld had cracked through as shown in Figure 1. The weld metal was thoroughly decarburized and contained numerous microfissures (Figure 2), while on the other hand the microstructure of the parent metal was normal for annealed 1¼ percent Cr, ½ percent Mo alloy (Figure 3). Analysis showed that the weld metal contained only 0.24 percent Cr and 0.13 percent Mo. Subsequent to discovery of the above faulty weld, every weld in six low alloy exchangers in the reactor effluent train was inspected for cracks by the magnetic particle method and samples for metal analysis taken from a number of welds.

The investigation revealed that welds in the exchangers were generally satisfactory, except that the longitudinal weld in the channel in each exchanger, which corresponded to the failed weld in the first case, was deficient in alloy content. In an exchanger that had operated in parallel under the same fluid conditions, a long, deep crack was found on the inside surface of the longitudinal channel weld. The other deficient welds exhibited no obvious defect that might be attributed to hydrogen attack. The analysis of the welds and approximate operating temperatures are given in Table 1.

According to the Nelson curves, hydrogen attack on the first two welds was to be expected. The molybdenum content of the third and fourth was sufficient to make them resistant. The last two might have escaped attack at the operating temperature even without alloy.

Conclusion

The cooperation of the fabricator of the exchangers was obtained in an effort to determine what deviation in welding procedures might have caused the welds to have less than specified chromium and molybdenum contents, but this was not definitely established. All of the difficulty was in one particular operation in making one particular kind of weld during fabrication. As can be seen, four welds would have been satisfactory for C-½ Mo steel and must have been made with

TABLE 1—Weld Composition

Exchanger	ELEMENT, PERCENT			Temperature, °F
	Chromium	Molybdenum	Carbon	
1-A (Leaked)	0.24	0.13	0.05	950
1-B (Cracked)	0.27	0.15	0.02	950
2	0.38	0.52	0.09	625
3	0.37	0.51	0.09	575
4-A	0.21	0.53	0.08	530
4-B	0.23	0.53	0.09	530

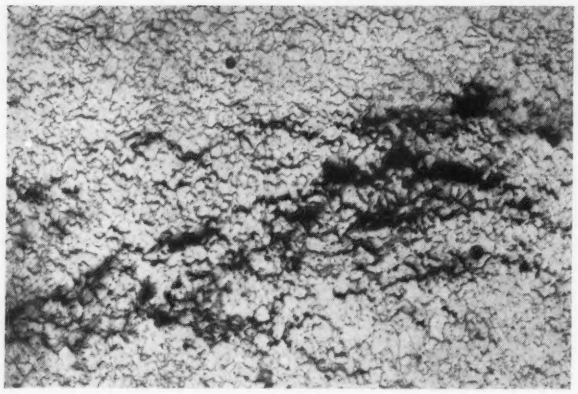

Figure 2—Photomicrograph showing fissuring in weld metal. Nital etch, 100X.

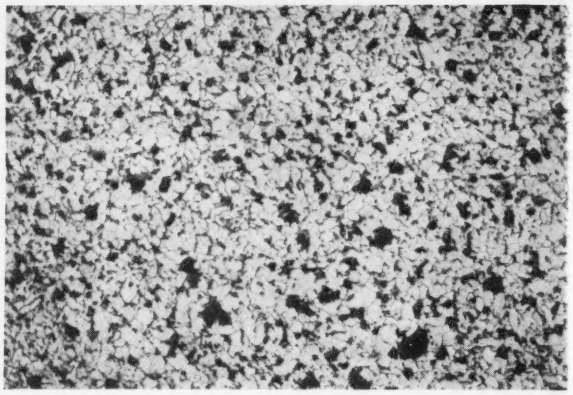

Figure 3—Photomicrograph showing structure of parent metal. Nital etch, 100X.

rod or wire containing molybdenum. The two that failed were apparently made with carbon steel rod or wire, since the minor alloy content would readily be accounted for by dilution of the parent metal.

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Any discussion of this article not published above will appear in December, 1961 issue.

Uptake of Hydrogen By Certain Organic Inhibitors During Pickling of Steel In Hydrochloric Acid*

By R. H. ANDERSON, E. R. ALLEN and P. A. van der MEULEN

Abstract

An apparatus was designed for and experiments conducted to determine precisely and simultaneously the volume of hydrogen evolution and steel corroded by inhibited and uninhibited hydrochloric acid. A theoretical concept of the probable reactions is described.

Hydrogen uptake and iron dissolved are tabulated for a number of experiments with and without inhibitors and with and without a hydrogen absorber. Influence of variables inherent in the experimental method is discussed with respect to accuracy of results. Evidence was found that the inhibitor DHQ displaces hexamine at the surface and thus prevents "uptake" of hydrogen by the hexamine. DHQ and hexamine were much more effective together in reducing the rate of hydrogen evolution than was DHQ alone.

4.3.2, 5.9.2, 5.8.3

Introduction

IN THE COURSE of research on Army Ordnance contracts, *6-methyl-3-(p-tolyl)-3, 4-dihydroquinazoline* hereinafter referred to as DHQ(1) and hexamethylene tetramine (hexamine) have been shown to inhibit appreciably a type of hydrogen embrittlement associated with 1095 steel during acid pickling. This embrittlement has been measured by the Moore-Fatigue Test.[1] An arbitrary combination much used in the experimental program has a composition of 0.0063 M DHQ and 0.036 M hexamine in 4.8 N HCl. The inhibitive properties of this reference combination were approximately equal to those of the specification combination.(1)

In connection with the study of the mechanism of the action of these substances, a new apparatus has been devised for measuring the volume of hydrogen evolved and the amount of iron simultaneously dissolved in the reaction of steel with an acid solution. The phenomenon of hydrogen evolution in connection with the action of acid on iron (or steel) has been studied with somewhat variable findings by a number of investigators. The articles by Bolognesi[2] serve as an index to work in this field, but no attempt is made to review the literature. Bolognesi[2a] concludes that definitely measurable amounts of hydrogen are absorbed by *Armco iron,* results clearly different from those reported herein on *high carbon steel.* Bolognesi's apparatus[2b] is much simpler and the description of his manipulations lacks clarity because of his brevity. It seemed therefore desirable to describe the apparatus and procedures used for tests reported herein in detail necessary for unmistakable clarity.

Special Apparatus Devised

A special apparatus and a procedure, described below in detail, have been developed to determine with greater accuracy than has been attained previously the volume of hydrogen evolved and iron dissolved. It has been used to measure the "uptake"(2) of hydrogen in the presence of certain organic inhibitors during the reaction of 1095 steel with 4.8 N HCl. It is hoped that this method of approach may be used to increase the understanding of the mechanism of hydrogen embrittlement of steel, and, in particular, the mode of action of embrittlement inhibitors.

Hydrogen embrittlement, long and extensively studied, is quite generally viewed as resulting from the diffusion of hydrogen into small voids in the steel, whereupon as it is converted to molecular hydrogen, an enormous pressure may arise resulting in blistering and/or embrittlement with resulting damage to the elastic and tensile properties of the steel. Todt,[3] in a succinct summary of this phenomenon, cites the very pertinent observations and interpretations of Zapffe, of Wachter, and their respective associates. Evans[4] gives a much more detailed review, with specific reference to the phenomenon as it accompanies acid pickling, and also includes an unusually interesting discussion of the "Types of Hydrogen Troubles."

The rate of the diffusion of hydrogen into the metal and consequent embrittlement might be decreased by affecting the rates of any of the following reactions where M: represents the surface of the metal containing many metal atoms with their electrons, and where H^+ is written in place of the hydronium ion:

$$H^+ + M: \rightarrow M:H^+ \qquad (1)$$

(chemisorbed hydrogen ions)

This reaction for the formation of chemisorbed hydrogen could be slowed.

$$2\ M:H^+ \rightarrow H_2 + M^{++} + M: \quad \text{or} \quad (2)$$

$$M:H^+ + H^+ \rightarrow H_2 + M^{++} \quad \text{or}$$

$$2\ M:H^+ \rightarrow M^{++} + H:M:H \quad \text{and}$$

$$H:M:H \rightarrow H_2 + M:$$

(chemisorbed hydrogen)

The release of molecular hydrogen at the outer surface could be accelerated, thus decreasing the time available for diffusion into the metal and the resulting embrittlement. An inhibitor, Inh, could be added which might be able to remove the chemisorbed hydrogen at the surface, thus preventing its diffusion into the metal.

$$H:M:H + Inh \rightarrow H_2Inh + M: \qquad (3)$$

If reaction (3) and the amount of chemi-sorbed hydrogen are both negligi-

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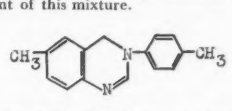
(1) DHQ. This compound has been isolated from the inhibitive mixture used in the U. S. Army Spec. No. 4-105, F-4a (2). Hexamine is an ingredient of this mixture.



(2) This "uptake" of hydrogen is viewed as apparent rather than real. It is recognized that inhibitors and related organic substances can be reduced without prior formation of atomic hydrogen. This will be discussed in a subsequent paper.

ROBERT H. ANDERSON received the PhD from Columbia University in 1954 for applying neutron spectroscopy to chemical analysis. From 1956 to 1957 he was an assistant research specialist at Rutgers. He is now an assistant Professor of Chemistry at Western Michigan University, in Kalamazoo, Michigan, He is interested in studies of hydrogen embrittlement and the effect of inhibitors on electrode potentials.

EDWARD R. ALLEN was graduated from the University of Illinois and received the PhD degree in organic chemistry at Cornell University in 1913. After six years of institutional and teaching work, he entered the employ of Du Pont Co., serving four years in research on azo dyes with the Organic Chemicals Department; 23 years as Director of Research on Pigment Colors, Pigments Department, Newark, N. J., and three years as Senior Research Associate in Wilmington, Delaware. In 1950 he took up research contract work at Rutgers, The State University, School of Chemisty, in the capacity of research specialist, a position from which he retired on December 1, 1960. His chief interests at Rutgers have been on corrosion for the Department of Defense and on certain problems for the U. S. Atomic Energy Commission, dealing with the polyphosphates and on the separation of the transitional elements.

P. A. van der MEULEN was graduated from Cornell University with the degree of BChem in 1913 and received the PhD degree from the same university in 1916 in the field of inorganic chemistry. He taught mineralogy and crystallography at Cornell until 1917, then was a research chemist for the Barrett Company until 1919. He came to Rutgers University in 1919 and became Professor of General and Physical Chemistry in 1925. In 1947 he became Director of School of Chemistry. His chief research interests are in the field of emulsions, rare earths and electrodeposition of metals.

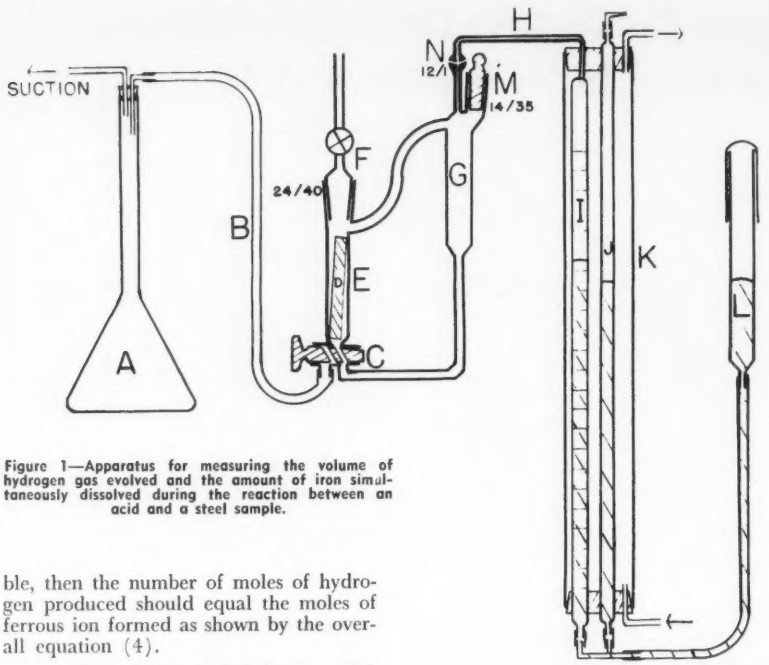


Figure 1—Apparatus for measuring the volume of hydrogen gas evolved and the amount of iron simultaneously dissolved during the reaction between an acid and a steel sample.

ble, then the number of moles of hydrogen produced should equal the moles of ferrous ion formed as shown by the overall equation (4).

$$Fe + 2\ H^+ \rightarrow H_2 + Fe^{++} \qquad (4)$$

The experiments described below permit the measurement of the hydrogen gas evolved and the amount of iron simultaneously dissolved during the reaction of a steel sample and acid. These results show the extent of reaction (3) and accompanying changes.

Experimental Method

The apparatus is depicted in Figure 1. Compartments E and G are made in one piece from heat resistant glass and are immersed in a constant temperature bath. Water from this bath is circulated also through the water jacket, K, containing a 50-ml buret, I, and a comparison tube, J, which is open to the atmosphere. The Hg-levels in I and J can be altered by raising or lowering the Hg-reservoir, L. A scale mounted on a board is placed behind K and observed by means of a telescope from a distance of about 10 feet. The hair line of the telescope is aligned with the horizontal lines on the scale and in turn can be used to determine when the two Hg meniscuses are at the same level. Except for the 1-mm capillary tube, H, all of the enclosed gas in chambers E, G, and I is maintained at the same temperature by the constant temperature bath.

The steel samples used in these experiments were half-inch diameter, cold drawn, annealed, 1095 steel rods. Surfaces of the samples were prepared by burnishing in a drill press with No. 0 emery cloth, followed by 6/0 production paper, after which the samples were rinsed with water and absolute alcohol and then dried. The ends were painted with an acid resistant paint, leaving a 6-cm length exposed.

Technique of Operation

The steel sample, D, is placed in the apparatus and acid is added to G so that no air is trapped in the tube below stopcock C. The rubber tube, B, and stopper with stopcock, F are attached and this part of the apparatus is placed in the constant temperature bath.

Before the experiment is started it is necessary to flush the system with hydrogen and to make certain that the acid has been saturated with hydrogen. For this purpose a special tube, which is drawn to a small tip and which reaches to the bottom of compartment G, is inserted at M; hydrogen enters at this point and exits at N. After saturating the acid with hydrogen, the tube at M is replaced with a solid glass stopper, and the buret is connected at N. Hydrogen is again passed through the system entering through B and exiting at F. After all air has been replaced with hydrogen, the stopcocks at C and F are closed. A vacuum is produced by lowering L in order to tighten all connections and to test for leaks. The system is then adjusted to atmospheric pressure, and the buret is read periodically to determine when equilibrium is reached in the apparatus. It is necessary that the gas space be nearly saturated with the vapors from the acid. This requires about one hour.

After essential equilibrium is reached and the initial buret reading taken with the Hg-levels in I and J the same, the stopcock at C is turned so as to admit acid from G into E sufficiently to cover the sample, after which C is closed. The time of admitting the acid is recorded as the start of the reaction. Additional buret readings may be obtained as frequently as desired by bringing the pressure to atmospheric and recording the buret reading and corresponding time. The rate of the reaction may thus be followed. The atmospheric pressure is measured at each observation. At the end of the experiment, M is opened; C is turned so as to remove acid from E thru B into volumetric flask, A, by means of suction; F is opened; and several flushings of chamber E and sample, D, are made by admitting distilled water through F. Repeated experimentation showed that unless the above procedures were rigorously followed reproducible results were not obtained.

The solution in flask A is then diluted to volume, and the iron determined by colorimetric analysis with the aid of a spectrophotometer. An adaptation of the orthophenanthroline method as used by Fortune and Mellon[5] was followed in which the solution was buffered with sodium acetate.

The experiments herein described were performed at 37.8 C and in 4.8 N hydrochloric acid solutions. Because of partial neutralization of the acid by the inhibitor, final acid concentration was slightly less in those experiments in which hexamine or DHQ were added as inhibitors.

Experimental Results

The millimoles of iron are computed from the results of the colorimetric analysis. The final buret reading is obtained by extrapolating from the last two observed values to the time at which the acid was drained from the reaction vessel. If the atmospheric pressure changes during the course of the experiment, the dead volume is altered and a corresponding correction must be made in the computed volume of hydrogen. The dead volume is the volume occupied by the gas which was present in E, G, and I at the start of the experiment. By means of the ideal gas law, the millimoles of hydrogen are computed from the corrected volume, the temperature and the pressure.

However, it is necessary first to correct the pressure by subtracting the vapor pressure of the acid solution from the final observed pressure. By interpolation from the International Critical Tables,[6] the vapor pressure of 4.8 N HCl is calculated to be 3.49 cm Hg at 37.8 C. If no hydrogen is taken up by the steel or by organic compounds present in the acid, then the millimoles of iron should be equal to those of hydrogen. The ratio of millimoles of hydrogen to millimoles of iron has been caculated for each experiment performed, and is given in Tables 1, 2, and 3. In Table 1, experiments H-12 to H-27 employ the reference inhibitor combination (vide supra). When this ratio is significantly less than one, "uptake" of hydrogen in the presence of the inhibitor has been assumed.

Table 1 shows "uptake" of hydrogen in the presence of DHQ is regarded as indeterminate, that in the presence of hexamine alone is slight but distinctly measurable, whereas the combination of DHQ and hexamine shows no determinable "uptake."

Table 2 shows a measurable hydrogen "uptake" in the presence of formaldehyde though it is slightly less than in the case of 0.036 M hexamine of Table 1. This concentration of hexamine should produce 0.216 M formaldehyde and 0.144 M ammonia by hydrolysis. The fraction of hydrogen "uptake" increases unmistakably with increasing concentration of hexamine.

A study of the action of a substance known to be readily reduced by hydrogen but without value as an embrittlement inhibitor was viewed as of interest. For this purpose nitroethane was chosen. The molarity was chosen to be equal to that of the formaldehyde formed by complete hydrolysis of 0.036 M hexamine. Table 3 shows nitroethane is, as predicted, a powerful absorber of hydrogen; the presence of DHQ has essentially no influence on this reaction.

If buret readings are made during the course of the experiment, it is possible to estimate hydrogen evolution rates. These vary by a factor of sometimes as high as two from experiment to experiment even when the composition of the solution is essentially unchanged. Nevertheless, general trends and differences are markedly apparent, and these have been condensed into Table 4. For convenience the evolution rates are expressed as $\lambda H_2/cm^2/min$ in which λH_2 refers to 0.001 ml or a microliter of hydrogen. The rate during the first interval was always greater than subsequent rates in all cases except that of 0.216 M nitroethane. Those experiments in uninhibited acid showed some tendency toward decreasing rates during the time of the experiment. The experiments in which hexamine acted as an inhibitor show marked decreases in the rates. With 0.036 M hexamine these decreases continue over a period of 1000 minutes or more, while with the higher concentrations of hexamine a more or less constant rate is reached after about 100 minutes.

TABLE 1—Hydrogen "Uptake" and Iron Dissolved

Ratio of millimoles of hydrogen evolved to millimoles of iron simultaneously dissolved during the action of 4.8 N HCl, both with and without added inhibitors, upon 1095 cold rolled annealed steel rods at 37.8C.

Exp. No.	Millimoles Fe	Ratio (H_2/Fe)	Average of Ratios	Fractional Hydrogen Uptake
No Inhibitor				
H-2	0.800	1.01		
H-3	0.943	1.05		
H-4	1.11	1.00		
H-7	1.22	1.00		
H-19	1.08	0.98		
H-35	1.39	0.98	1.00 ± 0.02	0.00
0.0063 M DHQ				
H-23	0.210	0.97		
H-24	0.137	0.97		
H-25	0.131	1.01	0.98 ± 0.02	0.02
0.036 M Hexamine				
H-10	1.09	0.92		
H-13	0.725	0.91		
H-15	0.735	0.87		
H-17	0.715	0.82		
H-20	0.840	0.85	0.87 ± 0.03	0.13
0.0063 DHQ + 0.036 Hex				
H-12	0.094	1.01		
H-16	0.148	0.87		
H-18	0.103	0.99		
H-21	0.190	0.94		
H-22	0.104	1.01		
H-26	0.129	1.03		
H-27	0.105	1.00	0.98 ± 0.04	0.02

Discussion of Results

On the basis of the accuracy of the various measurements and corrections involved in an experiment, the expected uncertainty in the calculated ratios is less than ± 0.02 in most of the experiments of Tables 1, 2, and 3. In several experiments the actual agreement is poorer than this. At least three possible additional causes might contribute to variations in the ratios.

First, the presence of an appreciable oxide film would cause a decrease in the observed ratio. Todt[7] and Evans[8] have reviewed evidence for oxide film formation. No oxide films were visible on the samples used, but these films usually are invisible. The highest reported value, 180 Angstroms, which Todt includes in his summary of film thickness is calculated to be equivalent to but 0.06 mg. (0.001 millimole) of iron dissolved in the experiments reported in this paper. This is negligible.

Second, any attack of the steel surface by the acid vapors during the time spent in attaining equilibrium before the start of the reaction will decrease the observed ratio. Sometimes a visible slight discoloration of the surface appears. The extent of this attack will vary somewhat from experiment to experiment. Since the ratios for uninhibited acid and acid containing DHQ are close to 1.00, no appreciable error is believed to be present from these first two sources.

Third, the experiments varied in duration as is indicated by the variation in the millimoles of Fe. Among experiments with the same inhibitor in Tables 1, 2 and 3; however, there is no trend relating the length of the experiment and the "uptake" of hydrogen.

Inhibitor Displaces Hexamine

Even allowing for these possible sources of error, the data of Tables 1, 2 and 3 clearly show differences in "uptake" of hydrogen with concentration and composition of the inhibitors used. Most of the experiments using DHQ and hexamine together give the apparent indication that no measurable quantity of hydrogen reacts with the inhibitors.

It would appear that DHQ is adsorbed on the surface more strongly than the hexamine and thus displaces it and prevents the "uptake" of hydrogen by hexamine or its hydrolysis product, formaldehyde. The experiments with 0.216 M and 0.72 M hexamine solutions might be interpreted to indicate that the surface is not completely covered with a monolayer at the lower concentrations and perhaps not even at a concentration of 0.72 M.

Results of this study do not distinguish between reactions (1) and (2), but permit an evaluation of the extent of reaction (3). On the basis of these results and in terms of the three reactions mentioned in the introduction, one can say that DHQ would be eminently good at slowing down either reaction (1) or reactions (2), simply by its overall ability as an inhibitor of metal attack.

Table 4 indicates that the rate of hydrogen evolution is cut by a factor of about 50 by DHQ alone and by a factor of about 200 by the combination of DHQ and hexamine. Table 1 would seem to show that DHQ in the concentration used has no perceptible ability to react permanently with hydrogen as in reaction (3) and thus cannot inhibit embrittlement in this manner.

On the other hand, hexamine conceivably might inhibit embrittlement by means of reaction (3) unless interfered with by DHQ and the results of Table 1 indicate the reality of this interference. Hexamine also can contribute to the inhibition of reaction (1) or reactions (2), especially when in combination with DHQ. A method of determining reactions (1) and (2) separately as well as information concerning the rate of diffusion of the chemisorbed hydrogen is necessary in order to answer completely the question of the extent of embrittlement inhibition in terms of the theory briefly outlined in the introduction.

Initial Rates Are Higher

Table 4 shows that except for nitroethane the initial rates are considerably

TABLE 2—Influence of Increasing Hexamine on Hydrogen "Uptake"

Similar to Table 1. Influence of increasing concentrations of hexamine and of its decomposition product, formaldehyde.

Exp. No.	Millimoles Fe	Ratio (H_2/Fe)	Average of Ratios	Fractional Hydrogen Uptake
0.216 M Formaldehyde				
H-37	0.568	0.98		
H-38	0.521	0.88		
H-39	0.623	0.91	0.92 ± 0.04	0.08
0.072 M Hexamine				
H-43	0.759	0.56		
H-45	1.152	0.65		
H-46	1.22	0.78		
H-47	1.02	0.74	0.68 ± 0.09	0.32
0.216 M Hexamine[1]				
H-28	1.61	0.47		
H-29	1.44	0.40	0.44 ± 0.04	0.56
0.72 M Hexamine[2]				
H-32	1.10	0.18		
H-42	2.26	0.13		
H-40	2.79	0.15	0.15 ± 0.03	0.85

[1] Final concentration of HCl was 3.9 M.
[2] Final concentration of HCl was 1.9 M.

TABLE 3—Influence of Nitroethane on Hydrogen "Uptake"

Similar to Table 1. Behavior of nitroethane (NE) alone and in the presence of DHQ.

Exp. No.	Millimoles Fe	Ratio (H_2/Fe)	Average of Ratios	Fractional Hydrogen Uptake
0.216 M Nitroethane				
H-30	3.15	0.30		
H-31	3.50	0.15		
H-36	1.91	0.24		
H-44	3.52	0.12	0.20 ± 0.07	0.80
0.0063 DHQ + 0.216 NE				
H-33	0.50	0.45		
H-49	0.67	0.24		
H-50	0.80	0.17	0.29 ± 0.12	0.71

TABLE 4—Evolution of Hydrogen With and Without Inhibitors

Rates of evolution of hydrogen gas by 1095 cold rolled annealed steel rods in 4.8 N HCl at 37.8C both with and without inhibitors. The rates are given in units of λ $H_2/cm^2/min$. Only an approximate range is indicated because the measured values vary from one experiment to another.

Inhibitor	Rate	Remarks
None	27 –45 20 –25 12 –20	Initial rate 5–15 minutes 20–60 minutes
0.036M Hexamine	14 –30 1 –3 0.5 –1 0.35–0.40	Initial rate 10–30 minutes 200–700 minutes 1100–1400 minutes
0.072M Hexamine	12 –15 2 –3 0.5 –0.7	Initial rate 10–30 minutes 200–1100 minutes
0.216M Hexamine	8 –9 1 –2 0.4 –0.5	Initial rate 10–30 minutes 100–1500 minutes
0.72M Hexamine	1 –2 0.3 –0.4	Initial rate 100–1000 minutes
0.216M Formaldehyde	6 –9 3 –5 2 –3	Initial rate 10–60 minutes 60–180 minutes
0.0063M DHQ	1.7 –2.5 0.2 –0.4	Initial rate 10–300 minutes
0.0063M DHQ and 0.036M Hexamine	2 –9 0.04–0.10	Initial rate 30–2000 minutes
0.216M Nitroethane	4 –9	Rate is essentially constant, 0–120 minutes
0.216M $C_2H_5NO_2$ and 0.0063M DHQ	2 –2.5 0.1 –0.2	Initial rate 15–1200 minutes

higher than those obtained after a few minutes. With 0.036 M hexamine this effect is prolonged in duration and the reaction continues to decrease in rate even after 700 minutes and finally reaches a rate approximately equal to that attained in 0.216 M hexamine in only 100 minutes. This slow decrease in rate can hardly be attributed to the time required to form an equilibrium adsorbed layer of inhibitor on the surface. It might be that in the case of hexamine some other slower reaction is taking place in the main body of the solution and not at the solution-metal interface. As has been summarized by Todt,[9] high initial rates have been observed previously.

Wickert and co-workers[10] have measured the rate of solution of iron in hydrochloric acid during the first few seconds both with and without hexamine. This is one of a series of papers in which particular attention is given to the structure of the surface. They summarize the evidence supporting the idea that there exist on the rough surface of steel active spots which adversely influence inhibitor adsorption and that not until these are removed by polishing or by dissolving does the inhibitor reach its full effectiveness. They found that the rate even during the first second was much greater than during later seconds. The effect is larger when hexamine is present. The results were interpreted to mean that the inhibitor forms an adsorbed layer on the steel. It is not possible to compare surfaces exposed in the experiments reported here exactly with those used by Wickert; however, it is recognized that the nature of the surface has an important influence on acid attack and extreme care was taken to process all samples in the same way.

Conclusions

The new apparatus and methods especially designed for the measurement of the simultaneous hydrogen evolution and iron dissolving during pickling of steel is capable of a higher degree of accuracy than is characteristic of prior approaches to this problem. Results show that the quantity of hydrogen taken up by uninhibited acid under the conditions of the reported experiments is too slight to be measured by even these refined techniques. DHQ in the concentrations used, while effective in reducing the total reaction, does not appreciably affect the H_2/Fe ratio. In the case of hexamine, on the other hand, the fraction of the hydrogen disappearing or unaccounted for is measurable and increases with the concentration of the hexamine. Interestingly enough DHQ in the presence of the hexamine effectively stops the reaction or absorption. The possible mechanisms involved in these changes will be discussed in a subsequent paper.

With the aid of the new apparatus and techniques continued study of the phenomenon of acid pickling will probably shed light on the mechanism of action of hydrogen embrittlement inhibitors.

Acknowledgments

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Any discussion of this article not published above will appear in December, 1961 issue.

High Temperature Scaling of Hafnium in Air*

By J. D. GADD and E. B. EVANS

Abstract

The scaling behavior of hafnium in air was studied in the temperature range of 600-1200 C. Hafnium initially scaled at a rate between parabolic and cubic, followed by a transition to a much faster rate because of scale cracking. The transition phenomenon was associated with a change from a compact black scale to a porous white scale. Nitrogen, in the presence of oxygen, was responsible for transition by a mechanism which may involve crystal structure and compositional changes in the scale during scaling.

The scaling behavior of hafnium and zirconium in air were found to be almost identical except that the latter exhibited growth whereas the former was dimensionally stable. 3.2.3, 6.3.21

Introduction

THE HIGH temperature scaling behavior of hafnium in various atmospheres has received little attention to date. In pure oxygen, hafnium oxidizes readily at a rate about one-third as fast as its sister metal zirconium.[1,2] In pure nitrogen, hafnium reacts slowly at a rate about one-fifth as fast as zirconium.[2,3] Hafnium, like zirconium, reacts in either of the pure gases to form a surface scale overlying a diffusion zone in which large quantities of gas are dissolved. Some pertinent physical properties of hafnium and its oxides and nitride are given in Table 1.

There has been no systematic study made of the scaling behavior of hafnium in air at high temperatures. Based on the behavior of zirconium in air,[2,4] the air-hafnium reaction should be of considerable interest. Zirconium, for example, reacts with both oxygen and nitrogen in the air at high temperatures. The initial black compact scale gives way, in time, to a white porous scale. Coincident with this change in scale color and morphology, the scaling rate exhibits a transition from a cubic (approximately) to a linear rate. More spectacularly, zirconium undergoes large dimensional changes during scaling—in some cases the lateral surface area of strip specimens increases as much as 300 percent.

In the present investigation the scaling behavior of hafnium in air was studied at 600-1200 C. As an aid to the interpretation of the kinetics of the reaction, the nature of the overlying scale and the underlying metal were examined by metallographic and X-ray techniques. For purposes of comparison, previous results with zirconium under comparable conditions are included.

Material and Procedure

Hafnium specimens (¾ x ¾ x 0.060 inch) were machined from 0.080 inch sheet which had been hot rolled at 800 C and annealed at 800 C for 15 minutes. The chemical analysis of this material is given in Table 2.

The specimens were polished through 600 emery paper, washed in acetone, and dried in alcohol prior to scaling. Scaling runs were conducted in a resistance-wound vertical tube furnace. Specimens were suspended in the furnace by a fine nichrome wire from one arm of a magnetically dampened chainomatic balance. In this manner continuous weight change of hafnium was obtained for times up to 100 hours or more for the temperature range 600-1200 C. Duplicate runs at each temperature showed reproducibility within 15 percent weight gain in all cases. Weighing errors were estimated to be less than 0.2 mg.

The gross external scale and the gas-contaminated zone in the underlying metal formed during scaling were examined metallographically and by X-ray diffraction at room temperature. The metallographic technique consisted of mechanical polishing through 600 emery paper and electropolishing-etching in a solution of glacial acetic acid and perchloric acid.[5] X-ray diffraction patterns of the scale *in situ* and after grinding to various depths were obtained by the diffractometer technique using nickel-filtered CuKα radiation.

Gadd

Evans

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Results

Scaling Kinetics

Weight gain in air as a function of time for isothermal runs in the temperature range 600-1200 C is shown in log-log plots in Figure 1. The rate of reaction may be described by the following equation:

$$\left(\frac{W}{A_o}\right)^n = kt$$

where

W = total weight gain
A_o = original surface area
t = scaling time
n, k = temperature-dependent constants

For the 600 C, 700 C, and the initial stages of the higher temperature runs the values of n (reciprocal slope) cluster about 2.3, indicating a rate between parabolic (n = 2) and cubic (n = 3). At 800-1200 C the nearly parabolic rate gives way, in time, to a linear rate of attack (n = 1). This transition in scaling rate has been observed in oxygen only after very long exposures.[1,5] In the case

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TABLE 1—Physical Properties of Hafnium and its Oxides and Nitride[2]

Metal or Compound	Crystal Form	Lattice Constant, Å a_o	b_o	c_o	Theoretical Density, gm/cc	Volume Ratio	Stability Range
Hafnium	HCP	3.195	...	5.057	13.09	...	Up to 1760C
	BCC	3.50[a]	...	....	....	...	1760—2222C (melting point)
HfO_2	Monoclinic[b]	5.11	5.14	5.28	10.22	1.51	Up to 1700C
	Tetragonal[c]	5.14	...	5.25	10.06	1.53	1700—2900C (melting point)
HfN	FCC	4.50	...	....	14.0	1.01	Up to 3300C (melting point)

[a] Extrapolated value at room temperature.
[b] $\beta = 99° 44'$.
[c] Lattice constants at 1920C

TABLE 2—Chemical Analysis of Hafnium

Element	PPM	Element	PPM
Zr	10000	Mn	25
Al	1100	Pb	<10
Fe	450	Si	<20
Cu	60	Zn	<50
Cr	800	Mo	<10
Mg	50	V	<20
Ti	300	Co	< 5
Ni	60	Sn	< 5

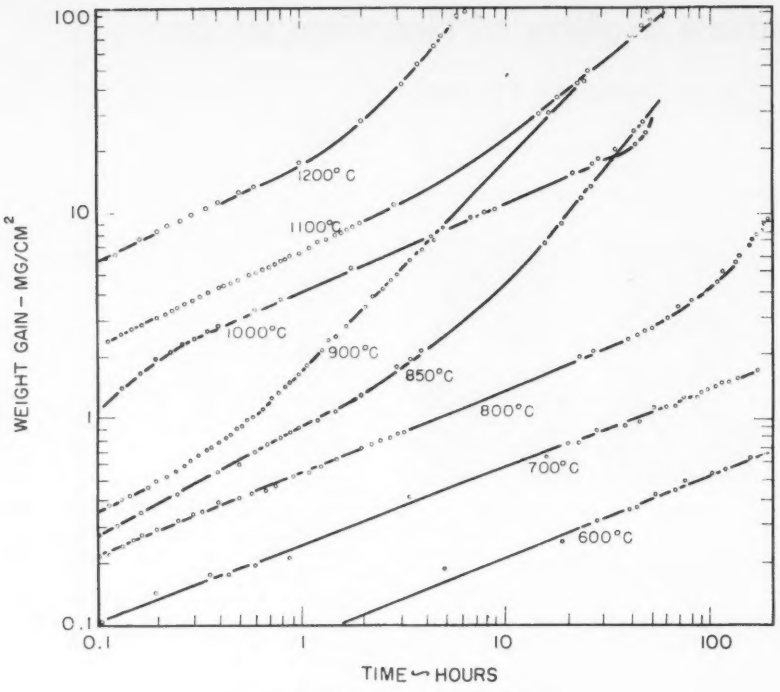

Figure 1—Weight gain for hafnium scaled in air.

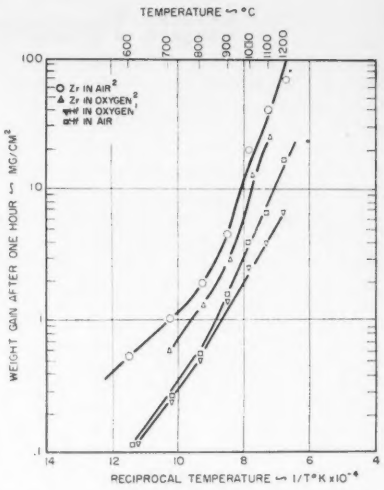

Figure 2—Weight gain after one hour in air and in oxygen vs reciprocal temperature for Hf and Zr.

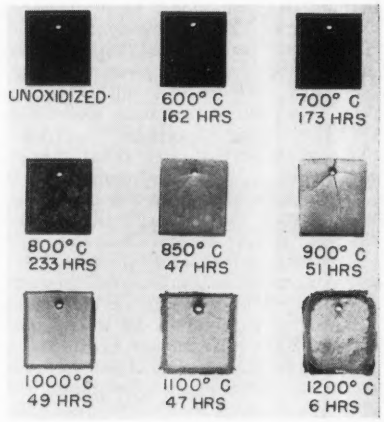

Figure 3—Hafnium specimens scaled in air.

of zirconium, linear kinetics were not observed for scaling in oxygen.[2]

To compare scaling rates of hafnium and zirconium, the weight gain after one hour in air and in oxygen are plotted to Arrhenius coordinates in Figure 2. Hafnium shows better scaling resistance than zirconium in either medium. It is also of interest that the scaling rate in air is greater than that in oxygen for both metals.

Nature of the Overlying Scale

Hafnium specimens underwent changes in scale color and compactness during scaling, as shown in Figure 3. Initial exposure in air at high temperatures resulted in the formation of a black compact scale. Below 800 C the scale remained black throughout the scaling runs lasting nearly 200 hours. At 800 C and higher, the initial black scale transformed to a white porous scale on continued heating. The white scale nucleated in a localized fashion underneath the black scale and mushroomed to the surface, thereby cracking the initial scale, Figure 4. The first appearance of the white scale coincided with the transition in the scaling rate. The cavitation type of attack continued until the entire surface was covered by white scale.

Glancing X-rays of the surface of the black and white scales showed no difference between the two, both producing X-ray diffraction patterns corresponding to monoclinic hafnium dioxide.

Nitrogen also participated in the scaling reaction, at least at 1100 and 1200 C. At these temperatures hafnium nitride was evident as a golden yellow undulating layer adjacent to the metal surface, Figure 5. Identification was made by grinding off the outer scale to various depths and x-raying the surface. All the lines reported for face centered cubic hafnium nitride[3] ($a_o = 4.50$Å) were found near the metal-scale interface, along with monoclinic oxide and a strong unidentified line (d = 2.93Å) which could be a reflection from a cubic or tetragonal structure, as discussed later.

To determine the diffusing species during scaling, marker tests were conducted at 700, 900, and 1100 C for times short of the rate transition. In all cases, painted stripes of green chromium oxide on hafnium metal were found on the scale surface after scaling, indicating anion diffusion inward and reaction with hafnium at the metal-scale interface.

Nature of the Underlying Metal

Metallographic examination of hafnium metal after scaling revealed many interesting features. Consider hafnium scaled at 800 C for 233 hours, Figure 4. Three distinct regions are evident, in order, under the scale overlay: (a) light etching metal surface layer, (b) darkened region containing line markings, and (c) central core.

Microhardness traverses across specimens scaled at various temperatures for times short of transition, Figure 6, clearly indicate the gas-contamination of hafnium. The faster diffusing gas is probably oxygen and not nitrogen since this is the case with zirconium scaled in air.[2] (Oxygen diffuses about twenty times faster than nitrogen in zirconium.)

Of interest too is that the gaseous penetration is not limited to the depth of the light-etching surface layer. In Figure 4, for example, gas contamination extended to a depth of 12 mils below the metal surface, or 6 mils beyond the line markings in this specimen.

The depth of gas contamination increased with temperature and time, i.e., the gas diffused faster in the metal than the metal was consumed by scale formation, until the transition in scaling rate was observed. The depth of contaminated metal then remained constant or decreased for longer scaling times. Wallwork and Jenkins[6] suggest that an increasing oxygen penetration zone is associated with the "parabolic" oxidation of titanium, whereas the transition to linear kinetics occurs subsequent to the establishment of a fixed depth of contamination.

Although the amount of gas (primarily oxygen) which dissolved in hafnium was not determined, the quantity was considerable as indicated by the exceptionally high hardness in the surface layers. Utilizing the dissolution of oxygen in zirconium at 600-1200 C as a guide, the amount of gas dissolving during air-scaling is probably about 25-50 percent of the total weight gain, the remainder contributing to scale formation.[2]

The cause of the zone of pronounced line markings beneath the light etching

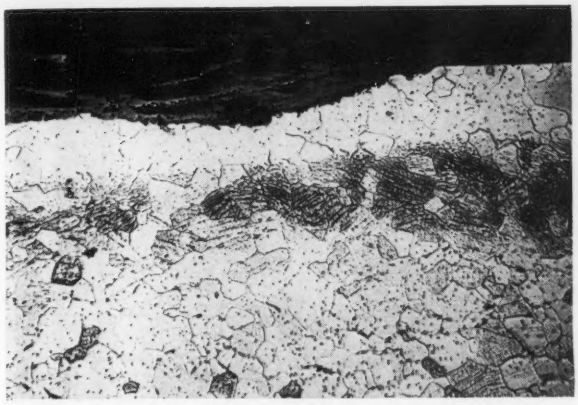

Figure 4—Hafnium scaled in air at 800 C for 233 hours showing pocket of porous white scale forming under black adherent scale. Electrolytic etch, 250X reduced to 170X.

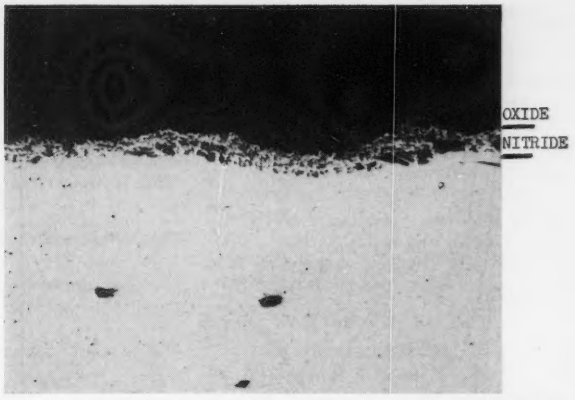

Figure 5—Hafnium scaled in air at 1200 C for one hour, showing yellow nitride layer between oxide and metal. Unetched, 250X reduced to 170X.

zone is not known. This is probably not a subscale zone since it does not originate at the metal-scale interface. It may be an unusual etching effect wrought by metal deformation on differential contraction of metal and scale on cooling. Or it may be due to metal deformation during scaling, as follows. The volume expansion involved in scale formation places the scale in compression which then may induce a sufficiently high tensile stress in the underlying metal to cause deformation. Plastic flow, if any, was negligible in the case of hafnium since no increase in lateral dimensions was detected, as contrasted to the spectacular growth observed with zirconium.[2]

Diffusion Coefficient of Oxygen in Hafnium

Klopp et al[7] have shown that hardness measurements of the diffusion zone, before transition, serve as a means of calculating the diffusion coefficient of oxygen in columbium, a metal similar in scaling behavior to hafnium. The equation utilized is:

$$\frac{H_m - H}{H_m - H_o} = \phi\left(\frac{x}{2\sqrt{Dt}}\right)$$

where H_m = hardness at the metal surface
H = hardness at distance x from the surface
H_o = uncontaminated core hardness
ϕ = probability (error) function
x = distance from the surface, cm
D = diffusion coefficient, cm^2 per sec
t = time, sec.

The diffusion coefficients of oxygen in hafnium calculated from hardness data are listed in Table 3 and plotted in Figure 7. The Arrhenius equation for these data is:

$$D = 1.6e^{\frac{-49,300}{RT}}$$

This is in good agreement with Pemsler's[8] results for dissolution of anodically deposited interference oxide films on hafnium:

$$D = D_o e^{\frac{-51,800}{RT}}$$

(The value of D_o is in fair agreement with that calculated by Chirigos from the data of Pemsler.[5] Assuming arbitrary solubility limits of oxygen in hafnium, Chirigos obtained the value 1.4 for 20 atomic percent, 0.47 for 30 atomic percent, and 0.14 for 40 atomic percent.)

For comparison, the diffusion coefficients of oxygen in zirconium are entered in Figure 7. These data show that oxygen diffuses somewhat faster in zirconium than in hafnium.

TABLE 3—Diffusion Coefficients of Oxygen in Hafnium

Temperature, °C	D, cm^2/sec
700	1.2×10^{-11}
800	1.4×10^{-10}
1000	3.1×10^{-9}
1100	1.7×10^{-8}
1200	1.3×10^{-7}

Discussion of Scaling Mechanism

Any mechanism to describe the scaling behavior of hafnium in air must take into account the active role of nitrogen in the presence of oxygen.

Consider first the scaling kinetics before transition. The fact that hafnium reacts faster in air than in oxygen is explainable in terms of anion defects and valency rules of semi-conductors as follows. During scaling, nitrogen dissolves in the anion-deficit oxide and creates additional defects in the anionic lattice since nitrogen has a higher valence than the oxygen it replaces. This permits a higher diffusion rate of anions through the dense black scale to the metal interface where reaction with hafnium occurs.

Anion vacancies would not be expected to play a major role in the linear scaling rate observed after transition. Here, the linear kinetics are due to direct admission of air through the porous white scale. However, if there exists a thin adherent continuous layer of oxide or nitride adjacent to the metal, lattice defects would contribute to the scaling reaction kinetics.

Since the surface of both the black and the white scale produced x-ray diffraction patterns of monoclinic oxide, the color change during scaling cannot be ascribed to a change in crystal structure. The black oxide may be anion-deficit while the white oxide is stoichiometric, as is the case with zirconium.[9]

The cause of the early transition in scaling rate in air is not known with definiteness. This phenomenon could not be correlated with scale thickness, weight-gain (see Figure 1), or depth of gas-contaminated zone. Nor is a high Pilling-Bedworth ratio in itself an adequate explanation, since this phenomenon occurs in air but not in pure oxygen, yet their P-B ratios should be almost identical.

Nitrogen dissolution in the metal may be a contributing factor to the early transition, as is the case with zirconium.[2] Other evidence of the harmful effect of nitrogen is that both hafnium and zirconium exhibit early transition during the corrosion of high nitrogen material in hot water and steam.[5] Conceivably, then, a critical amount of nitrogen can dissolve along with oxygen, and trigger a high rate of attack underneath the first-formed black protective scale. Or, nitrogen dissolution in the scale may lower the ductility of the scale so that stresses generated during scaling cannot be relieved by plastic deformation, and the scale fails by cracking.

Another possible explanation for the onset of linear reaction lies in the crystal structure changes that may occur during scaling in air. Although the monoclinic oxide is predominant in both the black and white scales, it is probably not the only oxide phase present. The X-ray results indicate that there may be an underlying oxide near the metal-scale interface. It is conceivable that this phase is a cubic or tetragonal oxide stabilized by nitrogen dissolution in the scale since these crystal structures, although not reported in the literature for hafnium oxide, are detected during high temperature scaling and anodic oxidation of zirconium.[2,9,10,11]

If the underlying oxide is face centered cubic and the single detected line (2.93Å) is the (111), then the lattice parameter is 5.07Å. Other lines of this presumed structure would be difficult to detect since (a) they overlap with those for the monoclinic oxide, which was present in all X-ray patterns of the scale, or (b) they are weak or missing

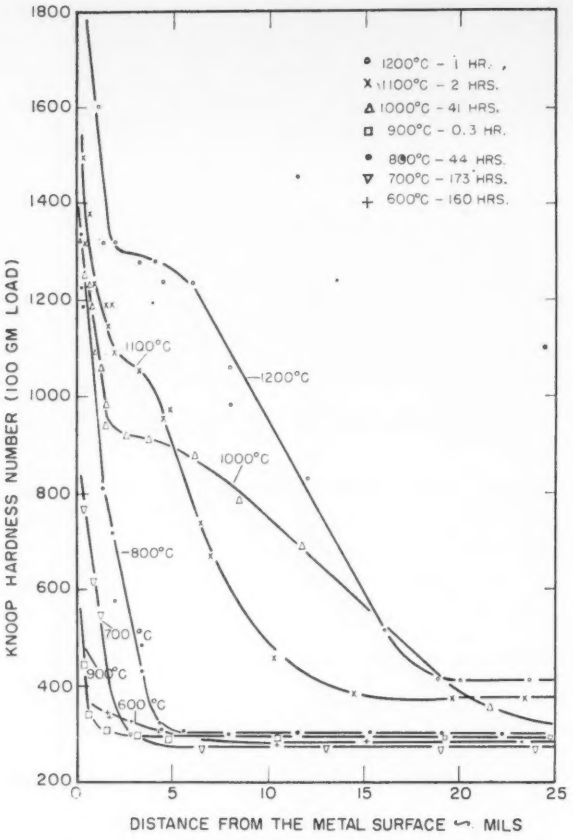

Figure 6—Hardness gradients after scaling hafnium in air, short of transition.

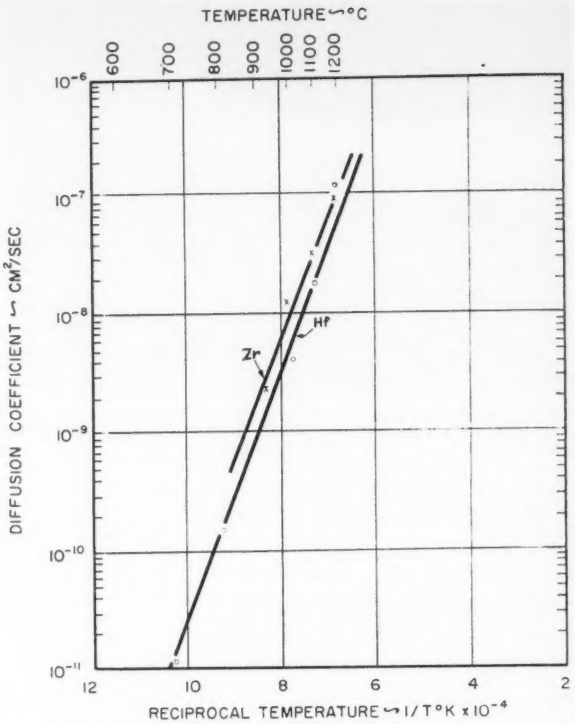

Figure 7—Diffusion coefficients of oxygen in hafnium and zirconium.

because of preferred orientation. This interpretation[11] finds some support in the fact that the lattice parameter of cubic zirconium oxide is 5.10Å, and it is the rule that comparable hafnium and zirconium compounds have nearly identical lattice parameters. Also, cerium dissolution in hafnium dioxide is capable of stabilizing the face centered cubic structure.[12]

If the underlying oxide is tetragonal with d(111) = 2.93Å and c/a near one (like tetragonal zirconium dioxide), then again the other lines may not be detected for the same reasons given above.

The crystal structural change during scaling may lead to cracking of the scale, as follows. In the early stages of scaling in air or oxygen, stresses arise from the epitaxial growth of oxide to metal. The lattice disregistry between these two phases amounts to about 10 percent, if one considers metal-to-metal distance of the closest packed planes, (0001) of close packed hexagonal hafnium and (111) of monoclinic oxide. In pure oxygen, the oxide possesses sufficient strength and/or ductility to withstand the stresses that build up during growth of the oxide. In air, however, the initial lattice registry of monoclinic oxide to metal is disrupted by the "nucleation" of a new oxide phase between the two. The interfacial stresses are now higher as the new oxide phase grows epitaxially with the two flanking phases, and eventually the scale cracks and a transition in the scaling rate occurs.

The nucleation and growth of the nitride phase, which was observed at the higher scaling temperatures, may not be responsible for a further rise in the scaling stresses. For example, considering the metal-to-metal distance in the closest packed planes, the (111) of the face-centered cubic nitride matches the (0001) of close packed hexagonal halfnium within 1 percent. Thus, the nitride finds an excellent coherency relationship with the metal and may be considered simply as an extension of the metal lattice.

Lastly, it is clear from the foregoing discussion that the air-scaling of hafnium is an involved problem and requires additional investigation. As a first step a phase-diagram study of the Hf-O-N ternary system is planned.

Summary

The reaction of hafnium in air at high temperatures (600-1200 C) initially followed a rate law between parabolic and cubic. Both an external scale and a gas-contaminated metal surface layer of high hardness were formed by the inward diffusion of anions.

Above 700 C the initial exponential rate gave way, in time, to linear kinetics. The co-presence of nitrogen and oxygen apparently accelerated the transition in scaling rate since this phenomenon has been observed in pure oxygen or nitrogen only after extremely long exposures. The transition was associated with a change from a black compact scale to a white porous scale. At the surface both types of scale produced X-ray diffraction patterns of monoclinic hafnium dioxide. There was evidence that a new oxide phase may have "nucleated" at the metal-scale interface during scaling. Also, face centered cubic hafnium nitride was definitely detected near the metal interface at the higher scaling temperatures. These crystal structure changes during scaling are believed to be responsible for scale cracking and rate transition.

The scaling behavior of hafnium and zirconium in air are almost identical, with the one major exception: zirconium exhibits growth (increase in lateral surface area of metal underlying the scale) whereas hafnium is dimensionally stable.

Acknowledgment

The hafnium used in this study was kindly supplied by A. H. Roberson of the Bureau of Mines.

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DISCUSSION

Comments by Anton deS Brasunas, American Society for Metals, Novelty, Ohio:

Growth of the Zr specimen is intriguing. Does "lateral expansion" infer contraction in the thickness in accord with Poisson's Ratio? If this is caused by oxide formation of higher volume, then you should get no growth with a sphere or cube. Have you investigated this?

Reply by Edward B. Evans:

We have scaled spheres and cubes of zirconium. No growth was obtained with spheres; however, one-inch cubes exhibited a definite earing effect, indicating that the surface layers of the metal had undergone deformation.

Questions by Harold L. Stevens, Wright Patterson AFB, Ohio:

1. Are suboxides of hafnium present in the oxide scale and if so, are they identified?

2. Is there any indication of a metal rich phase near the metal surface?

Replies by Edward B. Evans:

1. It is not known whether hafnium forms suboxides during scaling. One strong line from an unidentified phase was detected near the metal-scale interface, but it is not known whether this is a suboxide, dioxide, or nitride. With zirconium as a guide, it seems unlikely that a hafnium suboxide exists.

2. The surface metal, which probably contains as much as 25 atomic percent oxygen, is usually overlaid with a thin layer of nitride, an unidentified phase, and hafnium dioxide.

Questions by Warren E. Berry, Battelle Memorial Institute, Columbus, Ohio:

1. With reference to your reply to Dr. deS Brasunas, do you observe more expansion in one direction of zirconium cubes exposed to 800-900 C air?

2. Have you added nitrogen to zirconium and hafnium and then exposed them to oxygen to study the effect on oxidation rates?

Replies by Edward B. Evans:

1. The lateral expansion observed on the faces of a zirconium cube scaled at 900 C in air was the same in all directions, i.e., there was no effect due to preferred orientation. Also, sheet specimens exhibiting preferred and random orientation showed no difference in growth behavior.

2. Yes. Extensive scaling tests have been made with zirconium (Reference 2). Scaling of nitrided zirconium in oxygen resulted in an extremely high rate of reaction at 900 C, approaching a 'burning' rate. This illustrates the instability of zirconium nitride in the presence of oxygen.

Any discussion of this article not published above will appear in December, 1961 issue.

Continuous Recording of Pipe-to-Soil Potential vs Distance

By ROBERT L. DAVIS

Abstract

Equipment and a method useful in making a continuous recording of pipe-to-soil and certain other potentials significant in cathodic protection of underground metallic structures are described. The device consists of a wheel electrode, mechanically and electrically connected to a recording device which plots distances and potentials continuously as it is rolled along the earth's surface over a pipeline, or over an electrical field in the earth.

The method permits locating "hot spots" on lines with considerable accuracy, usually within a few feet. This radically improves the efficiency and effectiveness of protection at these points.

Further development of the device to record the direction of currents is contemplated using modified equipment. 4.5.3, 7.7

PIPE-TO-SOIL potentials have been used for many years to investigate corrosion of pipelines and underground structures. To obtain more detailed information on pipe-to-soil potentials, a method has been developed to record directly pipe-to-soil potentials vs position along the pipeline.

When a pipeline passes through soils with variations in chemical concentrations and moisture content, galvanic cells are set up on the outside surface of the pipe. Electrical currents leave the pipe surface at the anodic sections and reenter the surface at the cathodic sections. Anodic areas are the areas corroding and the cathodic areas are those protected. The electrical current flowing through the soil from the anodic areas to the cathodic areas creates a potential gradient in the soil surrounding the pipe.

O. C. Mudd[1] has published a paper describing a method of obtaining pipe-to-soil potentials by making a surface potential survey directly over the buried pipeline. A brief review of this method will be given. Anyone desiring a more detailed description of this method can obtain it from the National Association of Corrosion Engineers.[2]

Locating Focus of Corrosion

Figure 1 illustrates the method of obtaining pipe-to-soil potentials by means of a soil surface potential survey. The pipeline is contacted at Point 1 and a pipe-to-soil potential measurement is made. Contact with the ground usually is made with a copper-copper sulfate reference electrode. Successive potential measurements are made between Points 1 and 2, 2 and 3, etc., from which the pipe-to-soil potential at points 2, 3, 4, etc., can be calculated by noting polarity and potential between the various points. The purpose of contacting the pipe at point 7 is to check the computed pipe-to-soil potential at point 7.

Figure 2 shows a plot of the pipe-to-soil potentials computed from the data of Figure 1. The solid line indicates an anodic section, or area of concentrated corrosion, is at point 5. Because most surveys of this type are made by taking potential measurements at consecutive 50-foot or 100-foot intervals, the only way of knowing whether the most anodic point is at 5 exactly instead of some intermediate point between 5 and 4 or 6 is to make potential measurements at smaller intervals than the distance between 4 and 5, 5 and 6, etc. If the most anodic section does lie at an intermediate point to locate it requires making a series of measurements between points 4 and 6 and plotting these potentials.

An alternate method of obtaining the pipe-to-soil measurements is to contact the pipe at Point 1 and the copper-copper sulfate electrode is carried to points 2, 3, etc. and the pipe-to-soil potential measured directly. This method also requires taking additional readings to determine exactly where the most anodic spot is located.

When zinc or magnesium anodes are used for "hot spot" protection in relatively high resistance soils, i.e. above 5,000 ohm-cm resistivity, on bare pipelines, it becomes important to locate the anodic areas as closely as possible and practical. If the galvanic anode is placed at the most anodic spot, then it will be electrically connected at the point of least resistance and tend to "boost" the normal direction of current flow on the pipe line and provide the maximum degree of protection. If the galvanic anode is connected to the pipe 20 or 30 feet from the most anodic area, it is possible for the anode to be in an area that is slightly cathodic and this would tend to "buck" the normal direction of current flow. In this case, it is possible the corrosion at the "hot spot" would only be retarded, and not eliminated.

Wheel Electrode Is Used

Equipment developed to measure and record pipe-to-soil potentials is shown in Figure 3. It consists of three basic parts:

1. A copper-copper sulfate electrode in the form of a wheel.

2. A wire reel with slip rings holding between 2000 and 3000 feet of insulated flexible wire used to make electrical contact between the wheel electrode and the recorder. The wire passes over a counter wheel connected to the recorder chart drive by means of a flexible cable. By proper selection of gear ratios the recorder can plot potential vs distance so 1-inch equals 50 ft., etc., or to any desired scale.

3. The recorder is a self balancing potentiometer type instrument. A small 12 volt DC to 120 volt AC inverter is used so the recorder can be operated in

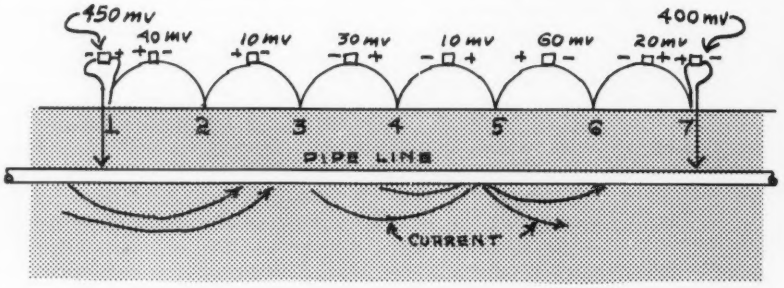

Figure 1—Results of the conventional method of obtaining pipe-to-soil potentials by means of a soil surface potential survey.

About the Author

ROBERT L. DAVIS—Since December 1960, senior corrosion engineer for Superior Oil Company. Earlier with Superior, he was research and development engineer. An Army Air Corps veteran of combat in the Mediterranean Theater during World War II, he graduated from University of California at Los Angeles with a BS in engineering in 1951, and with an MS in engineering in 1952. He has been employed by Superior since 1952.

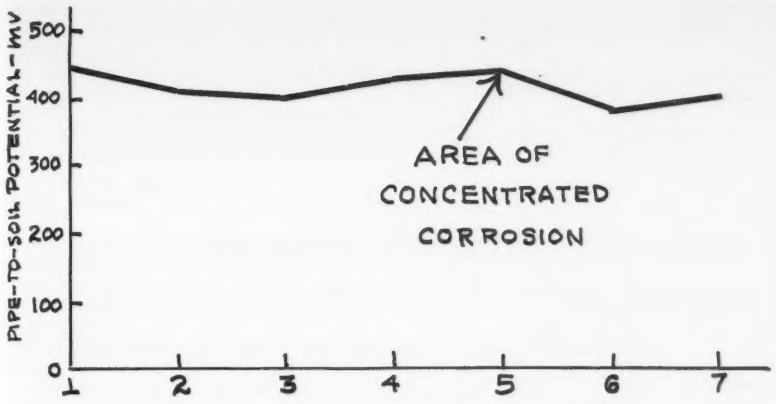

Figure 2—Plot results of pipe-to-soil potentials computed from data in Figure 1.

the field with a 12 volt automobile battery.

How Recorder Operates

For most operations, the recorder and wire reel are placed in the trunk of a car, back of a pickup truck or station wagon. The vehicle is placed in line with the pipeline, and if possible directly over the pipe near a pipeline contact point. The recorder is connected with the negative terminal to the pipeline and the positive terminal to the wire on the reel through the slip ring. The other end of the wire from the reel is connected to the wheel electrode. Thus, by rolling the wheel electrode directly over the pipeline a pipe-to-soil potential vs distance graph is obtained.

The two main advantages of this method over the "soil potential survey" method is that a continuous chart of the potential over every inch of the pipeline is obtained, and that a survey can be obtained in considerably less time. Having the equipment mobile, as in an automobile or pickup, it is easy to move from one contact point to the next and thus speed up making surveys on long lines.

Two main disadvantages of this apparatus are (1) it usually is necessary to wet the ground over which the survey is made; (2) vegetation, rocks, etc. may make it difficult to obtain a continuous survey directly over the pipeline. Also, many pipelines have natural barriers along the right-of-way which make a continuous pipe-to-soil potential survey impractical.

How Earth Is Watered

Where terrain permits, a truck with a water barrel or tank has been used successfully to wet the earth over which a survey is run as is shown in Figure 4. A hose from the water tank is directed in front of the wheel electrode, then a man pushes the electrode behind the truck.

A trailer hitch attachment between the truck and the wheel electrode has also been used successfully. Surveys have been made successfully where the pipe is under asphalt, but so far, no successful method has been found to run surveys on pipelines under concrete. It is believed that the success in making electrical contact between the electrode and earth through asphalt can be attributed to dirt mixed in the asphalt.

All tests made on concrete were in extremely arid areas. In areas where concrete is saturated with water, it may be possible to make satisfactory electrical contact between the electrode and earth through the concrete.

How Method Is Used

Figure 4 shows a section of a graph obtained for a 4-inch bare water line. This line was approximately one mile long. The cost of installing cathodic protection for the entire line was not justified but protection of "hot spots" was. Total time spent on the line was three hours for three men, most of which was spent locating the line. Making the actual pipe-to-soil potential survey took less than one hour.

The two "hot spots" shown on Figure 5 were the only ones located on the pipeline. One was over a length of approximately 20 feet of the line, the other over approximately 100 feet. When the pipe was uncovered to install magnesium anodes at these two spots, a leak was discovered less than one foot from the point marked to locate the most anodic spot of the 20-foot anodic area.

The apparatus is not limited to making pipe-to-soil potential surveys. Potential profiles of anode and cathode fields also have been made. This has been useful in determining interference on an unprotected structure caused by a structure under cathodic protection.

How to Locate Interference

To demonstrate how the location and type of a cathodic protection ground bed can influence interference on foreign structures, a series of earth potential profiles was made. The potential was measured between a "remote" electrode and the wheel electrode as it traversed a line between the anode bed and cathode, or protected structure. In the examples shown, the protected structure was an oil well casing. First, the potential profile was made with the cathodic protection rectifier turned off. Then, a potential profile over the same traverse was obtained with the rectifier turned on. The potential profiles with the rectifier on and the rectifier off are presented on the same graph. This change in the earth potential between the rectifier on and off indicates the relative amount of interference

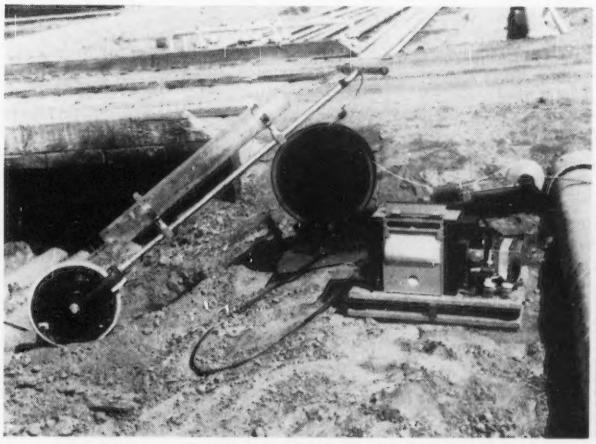

Figure 3—Copper-copper sulfate wheel electrode and recording equipment used to measure and record pipe-to-soil potentials. This device is patented.

Figure 4—Showing the method of operation, following tank which waters survey track immediately before the electrode.

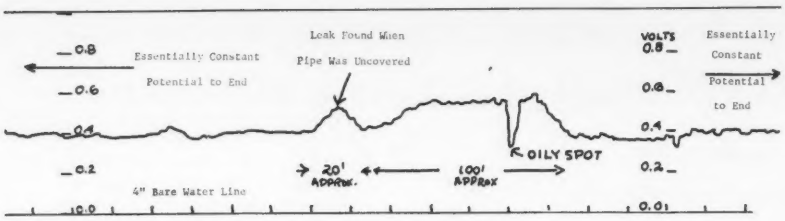

Figure 5—Section of a continuously recorded pipe-to-soil potential curve over a 4-inch bare pipeline.

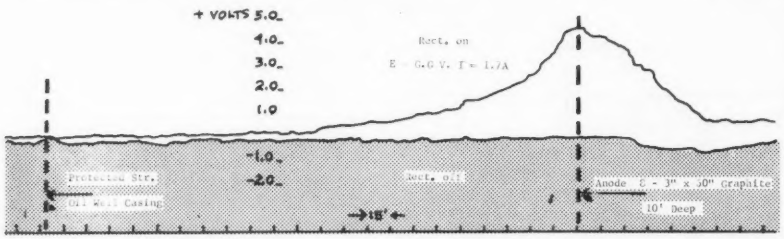

Figure 6—Continuous recording of earth potential profile between the anode and a protected structure using a conventional ground bed.

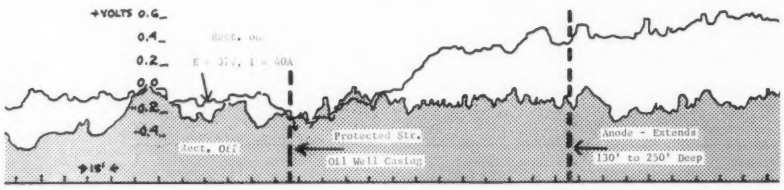

Figure 7—Continuous recording of earth potential profile between the anode and protected structure using a deep anode.

that may be expected on a foreign pipeline in this area.

Figure 6 shows the potential profiles between a ground bed and an oil well under cathodic protection. The ground bed consisted of eight 3 x 60-inch graphite anodes packed in coke breeze in 10-inch diameter, 10-foot deep holes. Potential measurements were between a fixed copper-copper sulfate electrode and the moving copper-copper sulfate electrode.

Figure 7 shows a potential profile similar to that for Figure 6. The difference being, the anode bed consisted of eight 3 x 60-inch graphite anodes placed in a 6-inch diameter hole 250 feet deep. The anodes extend from a depth of 130 to 250 feet and are backfilled with coke breeze.

Deep Anode Advantages Shown

Comparison of Figures 6 and 7 shows some of the advantages that are gained using a "deep" anode ground bed to reduce interference on adjacent unprotected structures. Figure 6 shows the large change that occurred in earth potential, near the earth's surface, when a voltage was applied between a conventional anode bed and an oil well under cathodic protection. In this case, 6.6 volts applied between the ground bed and oil well casing caused a resulting 1.7 amperes of current. This small voltage and current caused a 4.5 volt change in the earth potential in the area adjacent to the anode bed.

Figure 7 shows the relatively small change that occurred in the earth potential, near the earth's surface, when a voltage was applied between a "deep" anode bed and an oil well casing under cathodic protection. In this case, 37 volts applied between the ground bed and oil well casing caused a resulting 40 amperes of current. This relatively large voltage and current caused only a 0.5 to 0.6 volt change in the earth potential at a point on the earth's surface directly over the deep anode bed.

Attenuation Curves Plotted

The wheel-electrode has been used also to obtain attenuation curves on a protected structure for both galvanic and impressed current anodes. Other types of potential measurements also can be made with the apparatus and these will be investigated. One is to use two of the wheel electrodes connected parallel to each other to determine direction of earth currents. This will require a "zero center" type recording voltmeter, which will necessitate a few modifications of existing equipment.

At present it is believed the most attractive application of this equipment is for pipe-to-soil potential surveys to locate "hot spots" on unprotected pipelines. This equipment should make it economically attractive to run "hot spot" surveys on long pipelines across open country, especially where it is possible to drive a vehicle directly over the pipeline.

References

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Any discussion of this article not published above will appear in December, 1961 issue.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Tentative Recommended Minimum Requirements For Hot Applied Wax-Type Protective Coatings And Wrappers for Underground Pipelines

A Report of NACE Technical Unit Committee T-2L*
On Wax-Type Pipe Coatings and Component Wrappers

NACE TECHNICAL COMMITTEE REPORT
Publication 61—11

Abstract

This report lists tentative recommended minimum requirements for hot applied wax-type protective coatings and wrappers used on underground pipelines. Materials discussed include primers, microcrystalline-type wax coatings, shield coating, and outerwrap. Physical properties and test methods are reported for all of these materials with the exception of outerwrap. Physical properties and test methods also are given for the following specific types of component wrappers: plastic film, reinforced laminated plastic films, multilayer plastic asbestos wrappers, envelope type reinforced plastic film and wax saturated asbestos felt. Other matters discussed include application and maintenance of coatings, priming, electrical inspection, handling of materials, protection of joints and fittings, coating repairs and suggested material systems. 5.4.10, 8.9.3

Objective

THE ULTIMATE objective in the installation of hot applied wax coating and wrapping protective system for underground pipe is to provide and maintain a continuous coating of wax on the pipe surface over-wrapped with a component wrapper. Such a system provides protection to the pipeline against a corrosive environment.

Description

Wax wrapping requirements for pipe lines shall consist of an application of a microcrystalline-type wax coating over a compatible primer when so specified, followed by an over-wrap of a component wrapper. When additional mechanical protection is required, an application of shield coating shall be applied over the primary wrapper, and over-wrapped with heavy kraft paper or suitable outerwrap to protect it during shipment and handling. When rock fill is encountered, selected backfill or prefabricated rock shield shall be specified for additional protection.

Materials(1)

Primer—(When specified by manufacturer or purchaser.)

The primer shall be composed of a base compatible with the wax coating, suitably blended to produce a liquid coating which may be applied cold by brushing or spraying, and which will produce a satisfactory bond between the metal pipe surface and the microcrystalline-type wax coating. The primer shall have good brushing, spraying and leveling properties. It shall be homogeneous, free from water and shall meet the following requirements:

Properties	Physical Requirements	Test Method
Flash point (TCC), min.	95 F	ASTM D-56-56
Furol viscosity @ 77 F	10-20	ASTM D-88-56
Residue from distillation to 680 F, volume % by difference	29	ASTM D-402
Percent of solids by weight, min.	30	(ASTM D-154-58 (Method A

* John O. Mandley, Michigan Consolidated Gas Company, Detroit, Michigan, chairman.

(1) Properties tabulated are nominal values of materials in common use and are not intended to be limiting except as to minimum material standards outlined herein.

Microcrystalline-Type Wax Coating

The microcrystalline-type wax coating shall be permanently inert, flexible, waterproof, adhesive, and of high dielectric strength. It may be blended with a suitable wetting agent and rust inhibitor. This coating shall be homogeneous in character and shall meet the following requirements when tested in accordance with the methods hereinafter enumerated:

Properties	Physical Requirements	Test Method
Specific gravity @ 77 F	0.90	ASTM D-70-27
Wt. per gal. @ 77 F (lbs.)	7.70	
Penetration @ 77 F, 100 gr., 5 sec.—max.	38	ASTM D-5-52
Melting point	160 F	ASTM D-127-49
Flash point—min.	500 F	ASTM D-92-45

Shield Coating

The shield coating is designed to provide additional protection, sealing, and shielding of the microcrystalline-type wax coating and wrapping combinations in yard or mill application. Use of shield coating will reduce handling damage in the moving and stockpiling of mill or yard wrapped pipe. The shield coating shall meet the following requirements when tested in accordance with the methods hereinafter enumerated:

Properties	Physical Requirements	Test Method
Specific gravity @ 77 F	1.00	ASTM D-70-27
Wt. per gal. @ 77 F	8.5	
Melting point	200 F	ASTM D-127-49
Penetration @ 77 F, 100 gr., 5 sec.—max.	21	ASTM D-5-52
Flash point—min.	550 F	ASTM D-92-56

Component Wrappers

The pipe line wrapper should consist of a plastic film or lamination of films, or wax saturated asbestos felt plain, or a plastic component. The wrapper may or may not be reinforced. Such wrapper components shall be compatible with both the microcrystalline-type wax coating, and the shield coating, if double coated. The wrappers shall meet the following requirements when tested in accordance with the methods hereinafter enumerated. The wrappers that are described below are not listed in order of preference.

Type A—Plastic Film (Polyvinylidene chloride)

Properties	Physical Requirements	Test Method
Thickness, mils	2.0	ASTM D-374-42
Tensile strength, psi	13000-20000	ASTM 882-56
Bursting strength, psi	60	ASTM 774-46
Weight per sq. yd., lbs.	0.177	
Dielectric strength, volts	6000	ASTM D-257-58

Type B—Reinforced Laminated Plastic Films (Glass-acetate wrapper)

Properties	Physical Requirements	Test Method
Thickness, mils	7.0	TAPPI T 411 m
Tensile strength, psi	130	TAPPI T 403 m
Bursting strength, psi	89	TAPPI T 403 m
Saturant, percent of dry wt.	70	Manufacturer
Weight per sq. yd., lbs	0.36	
Dielectric strength, volts	5600	ASTM D-149-44

Type C—Multilayer Plastic Asbestos Wrappers, Reinforced or Unreinforced *(Polyethylene-asbestos, wax saturated)*

Properties	Physical Requirements	Test Method
Thickness, mils	25.0	TAPPI T 411 m
Tensile strength, psi	48	TAPPI T 404 m
Bursting strength, psi	40	TAPPI T 403 m
Saturant, percent of dry wt.	21	TAPPI T 405 m-45
Weight per sq. yd., lbs.	1.01	
Dielectric strength, volts	6100	ASTM D-257-58

(*Acetate-asbestos, wax saturated*)

Properties	Physical Requirements	Test Method
Thickness, mils	30.0	TAPPI T 411 m
Tensile strength, psi	50	TAPPI T 404 m
Bursting strength, psi	40	TAPPI T 403 m
Saturant, percent of dry wt.	51	Manufacturer
Weight per sq. yd., lbs.	1.35	
Dielectric strength, volts	5600	ASTM D-149-44

Type D—Envelope Type Reinforced Plastic Film (Polyethylene-reinforcing-polyethylene)

Properties	Physical Requirements	Test Method
Thickness, mils	12.0	TAPPI T 411 m
Tensile strength, psi	70	TAPPI T 404 m
Bursting strength, psi	75	TAPPI T 403 m
Saturant, percent of dry wt.	12	TAPPI T 405 m-45
Weight per sq. yd., lbs.	0.53	
Dielectric strength, volts	15700	ASTM D-257-58

Type E—Asbestos Felt, Wax Saturated

Properties	Physical Requirements	Test Method
Thickness, mils	25.0	TAPPI T 411 m
Tensile strength, psi	32	TAPPI T 404 m
Bursting strength, psi	30	TAPPI T 403 m
Saturant, percent of dry wt.	51	Manufacturer
Weight per sq yd., lbs.	1.2	
Dielectric strength, volts	2100	ASTM D-149-44

Outerwrap

Forty lb. minimum weight kraft may be used as an outerwrap. Other suitable wraps include rag and asbestos felts.

Application and Maintenance

Preparation of Surfaces

All oil, grease, moisture, loose scale and dirt on the surfaces of the metal shall be removed prior to application of the primer, and/or wax coating. Metal surfaces shall be mechanically cleaned by either grit blasting, wire brushing, and dusting or scraping (if necessary).

Priming (When specified by manufacturer or purchaser.)

The primer shall be applied uniformly to the clean, dry metal surface in a manner recommended by the manufacturer and approved by the engineer.

Microcrystalline Wax Coating Application

The wax coating shall be flooded directly on the pipe surface at temperatures recommended by the manufacturer and approved by the engineer. Coating shall be applied in a continuous film and be well adhered to the pipe surface.

Wrapper Application

The wrappers shall be applied in a uniform snug fitting over-lapping pattern following the application of the hot wax coating. The wrapper tension shall be such as to assure a tight application of the wrapper over the coating. The overlap at the edges of the wrapper shall be maintained as specified by the engineer.

Electrical Inspection.

An electrical inspection of the completed coating and wrapping system may be made with voltages properly set so as to detect defects in the coating system, but so as not to damage the otherwise acceptable coating system.

Handling of Materials and Coated and Wrapped Pipe

1. All coating and wrapping materials shall be transported and stored in such a manner as to prevent damage or contamination. The coating and wrapper shall be maintained moisture and dirt free at all times prior to, and during the time of application.

2. The coated and wrapped pipe shall be handled in such a manner as to minimize damage in shipment and storage. All supported areas of the protected pipe shall be inspected, and damaged areas repaired prior to installation.

3. Wherever the bottom of the ditch contains projecting rocks or hard objects which might puncture the protective coating, the bottom of the ditch shall be padded in an approved manner.

4. The coated and wrapped pipe line shall be lowered in a manner satisfactory to the engineer.

5. The ditch shall be backfilled with material free from hard or sharp objects which may damage the coating.

6. Where directed by the engineer, the use of a rock-shield or additional layers of coating and wrapping material may be substituted for (a) padding the bottom of the ditch, and (b) using selected backfill materials.

7. Backfilling shall be conducted at all times in a manner to prevent damage and abrasion to the protective coating and wrapping on the pipe.

Protection of Joints and Fittings

Pipe joints, couplings and all fittings shall be protected with a coat of primer when specified, following by a hot wax coating and an application of component wrapper. All such joint protection shall be performed in a manner approved by the engineer.

Equipment

All equipment used in these operations shall be of a type satisfactory in all respects to the engineer. No equipment shall be used which may cause damage to the pipe or protective system.

Miscellaneous Provisions

Where river weights or supporting or anchoring devices are used, these objects shall be attached or applied in such a manner as not to damage the protective coating system. Preferably the protective coating shall be protected with rock-shield.

The engineer shall determine the extent of cathodic protection required. When cathodic protection is installed, it shall be installed in accordance with procedures of the T-2C Committee of the NACE.

Coating Repairs

When excavations are made for leak repairs, tie-ins, lateral connections, or any other purposes, all damaged or deteriorated coatings shall be repaired.

Suggested Material Systems

Mill or Yard Application:

1 coat of primer when specified
1 coat of hot applied wax coating—1/32 inch average or as specified
1 wrap of component wrapper
1 coat of hot applied shield coating
1 wrap of kraft paper or suitable outerwrap

Traveling Machine Application:

1 coat of primer when specified
1 coat of hot applied wax coating—1/32 inch average or as specified
1 wrap of component wrapper
1 wrap of kraft paper or suitable outerwrap when specified

Hand Application:

1 coat of primer when specified
1 coat of hot applied wax coating—1/32 inch average or as specified
1 wrap of component wrapper

Any discussion of this article not published above will appear in December, 1961 issue.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Tentative Recommended Specifications And Practices for Prefabricated Plastic Films For Pipeline Coating

NACE TECHNICAL COMMITTEE REPORT

Publication 61—12

A Report of NACE Technical Unit Committee T-2K* On Prefabricated Plastic Film for Pipe Line Coating; Prepared by Task Group T-2K-1** on Standards

Abstract

Tentative recommended specifications and practices are drawn up here for prefabricated plastic films used for coating pipelines. Materials covered include pressure-sensitive plastic tapes, prefabricated plastic film with adhesive coating separately applied, tape laminates, and extruded plastic coatings. A general description is given of each of these four types of coatings materials followed by a table of physical properties and test methods. Protective overwraps are discussed briefly as is cathodic protection. Topics considered with respect to application of prefabricated plastic films to pipe include cleaning, priming, coating and wrapping, and inspection and repair.

5.4.10, 8.9.3

1. Introduction

THE SPECIFICATIONS and practices in this report are based on the service records of several types of prefabricated plastic films. The properties tabulated do not in themselves constitute a criterion for the selection of a material for use as a pipeline coating. It is possible that a material possessing the characteristics listed would not perform satisfactorily as a protective coating for underground piping. Conversely it is possible that a plastic material having properties quite different from those listed would perform very well as a pipeline protective coating. It is the purpose of this specification to describe, without setting limiting requirements, prefabricated plastic materials which are successfully established as pipeline coatings.

2. Coating Requirements

Prefabricated plastic films for pipeline coating should have the following permanent properties: high electrical resistivity, pliability, conformability, resistance to corrosive environments, low moisture absorption and permeability, and suitable adhesion to the pipe surface. Coatings also should be of such a nature as to resist excessive mechanical damage during normal application operations.

3. Materials

3.1 Coating Materials

Materials covered by this specification are classified as follows:

Type 1. Pressure-sensitive plastic tapes.

Type 2. Prefabricated plastic film with adhesive coating separately applied.

Type 3. Tape laminates.

Type 4. Extruded plastic coatings.

The range of property values tabulated in the several specifications are nominal values of the materials in common use, and are not intended to be limiting.

Type 1—Plastic Tapes, Pressure-Sensitive

General Description: These products are composed of films such as polyethylene and polyvinyl chloride, carrying elastomer-based adhesives.

Property	Nominal Range	Test Method
Thickness, total, mils	10-20	ASTM D- 100-55T
Tensile strength, lbs./in. width	15-45	ASTM D-1000-55T
Elongation break, %	60-400	ASTM D-1000-55T
Adhesion, ozs./in. width	20-60	ASTM D-1000-55T
Water-vapor-transmission rate, gms/24 hrs./100 sq. in.	0.05-2.0	ASTM E96-53T
Moisture absorption, %	0.02-0.2	ASTM D-570
Dielectric strength breakdown, volts/mil	750	ASTM D-1000-55T
Insulation resistance, megohms/in. width	> 500,000	ASTM D-257

Type 2—Prefabricated Plastic Film, Adhesive Coating Separately Applied

1. Plastic Film Over Wax Adhesive

A—Plastic Film. General Description: A film of polyvinylidene chloride plastic pigmented with aluminum.

Property	Nominal Range	Test Method
Thickness, mils	1-2	ASTM D-1000-55T
Specific gravity	1.68	ASTM D-792-50
Water-vapor-transmission rate, gms./24 hr/100 sq. in.	0.10	ASTM E96-53T
Water absorption'	Negligible	ATSM D-570
Tensile strength, lbs./sq. in.	13,000-20,000	ASTM D-882-54T
Elongation, %	45-80	ASTM D-882-54T
Bursting strength-Mullen, lbs./sq. in.	60	TAPPI

B—Wax Adhesive. General Description: Microcrystalline wax. Properties of this adhesive are given in Table 1. Data are reported over nominal range both for hot applied and cold applied coatings.

Type 2—Prefabricated Plastic Film, Adhesive Coating Separately Applied

2. Plastic Film Over Solvent Release Cement System

General Description: A polyvinyl chloride film used in conjunction with a separate one-part solvent release cement system. The latter consists of a cold applied cement made up of a vinyl resin, or group of resins, as a base and a group of organic solvents acting as a carrier. Physical properties of this film are reported in Table 2.

Type 3—Tape Laminates

General Description: Products consist of laminates of polyvinyl chloride film and butyl rubber (commonly used with an adhesive primer).

Property	Nominal Range	Test Method
Thickness, Total mils	10-35	ASTM D-1000-55T
Tensile strength, lbs./in. wid.	15-16	ASTM D-1000-55T
Elongation at break, %	150-400	ASTM D11000-55T
Water-vapor-transmission rate, gms/24 hr/100 sq. in.	0.05-1.2	ASTM E96-53T
Moisture absorption, %	0.02-2.0	ASTM D-570
Dielectric strength breakdown, volts/mil	1000	ASTM D-1000-55T
Insulation resistance, megohms/in. width	>500,000	ASTM D-257-52T

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TABLE 1—Physical Properties of Wax Adhesive

Property	Nominal Range		Test Method
	Hot Applied	Cold Applied	
Melting point, Degrees F	165-175	140-155	ASTM D-127-49
Viscosity, SSU, at 120 F	75-100	16- 18	ASTM D- 88-44
Penetration, needle 100 gms. 5 sec. 77 F	28- 32	38- 42	ASTM D-5-49
Specific Gravity			
At 32 F	0.947	1.026	ASTM D- 70-27
At 77 F	0.928		ASTM D- 70-27
At 170 F	0.816		ASTM D-287-39
At 250 F	0.789		ASTM D-287-39
Flash Point, Degrees F Min.	525	410	ASTM D- 92-45
Fire Point, Degrees F Min.	550	475	ASTM D- 92-45

TABLE 2—Physical Properties of Plastic Film Used Over Solvent Release Cement System

Property	Nominal Range			Test Method
	70 F	100 F	140 F	
Tensile, psi lgth/wid.	3600/3100	3200/2500	2300/2100	ASTM D-882
100 Modulus, lgth/wid.	2500/2400	2100/1900	1800/1700	ASTM D-882
Elongation, %, lgth/wid.	300/ 300	250/ 200	170/ 160	ASTM D-882
Thickness, mils	10-20			ASTM D-100-55T
Groves tear, lgth/wid. (gms/mil)	244/ 223			ASTM D-882
Elmendorf tear lgth/wid. (gms/mil)	400/ 450			Method 5132 Spec. CCC-T-191
Water absorption, %	0.03-0.20			ASTM-570-42
Water-vapor transmission rate, gms/sq. meter/ 24 hr.	0.9			ASTM E-96-53T
Masland SPI cold crock	Passes O °F			SPI
Tabor abrasion, % loss	0.18-0.045			ASTM D-1242
Dielectric stg. breakdown, volts/mil	1270			ASTM D-495

Type 4—Extruded Plastic Coatings

General Description: Product consists of an extruded polyethylene coating and an adhesive mastic applied at a mill or yard.

Property	Nominal Range	Test Method
Thickness, total, mils	30-50	ASTM D-1000-55T
Tensile strength, psi	350	ASTM D-638-52T
Elongation, %	100	ASTM D-638-52T
Water-vapor-transmission rate, gms/24 hr./100 sq. in.	0.02	ASTM E-96-53T
Moisture absorption, %	0.02	ASTM D-570
Dielectric strength, breakdown, volt/mil	1000	ASTM D-149-44
Insulation resistance, megohms/in. width	>500,000	ASTM D-257-52T

3.2 Protective Overwrap

Protective overwraps are required under many application conditions; under some soil conditions, the protective overwrap may be omitted. The necessity for and choice of overwrap materials would be dictated by the conditions involved.

4. Application of Prefabricated Plastic Films to Pipe

4.1 Cleaning

Pipe surfaces shall be thoroughly clean and dry at the time the coating is applied, and shall be free of dirt, grease, oil, rust, scale or other foreign matter. Welds shall be cleaned of all welding slag, splatter, and scale, and shall be allowed to cool before the coating is applied.

4.2 Priming

When a primer is required, a uniform and continuous coat shall be applied in accordance with accepted practices. The primer coverage and curing time should be such as to insure maximum bond between the pipe and the coating.

4.3 Coating and Wrapping

The specific application procedure used for each type of prefabricated plastic film coating shall be as described by the manufacturer. Adequate provision shall be made to protect the coating from physical damage during the pipe handling, lowering and backfilling operations.

4.4 Inspection and Repair

Inspection of the coating shall be made just prior to lowering-in and all damaged areas shall be repaired. When electrical inspection is performed it shall be in accordance with standard accepted practice for the type of coating involved.

5. Cathodic Protection

5.1—The owner's engineer shall determine the extent of cathodic protection required.

Any discussion of this article not published above will appear in December, 1961 issue.

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Rubber Linings, Hard and Soft For Resistance to Corrosion

NACE TECHNICAL COMMITTEE REPORT

Publication 61—13

A Report of Technical Unit Committee T-6A* On Organic Coatings and Linings for Resistance to Chemical Corrosion. Prepared By Task Group T-6A-1** on Rubber Linings

Abstract

Characteristics, properties and uses of rubber linings are discussed generally and in particular. Some problems associated with the design of equipment to be lined are mentioned. Linings are divided into three categories: Hard, semi-hard and soft, and the indicated uses, techniques appropriate to and deficiencies of each are considered.

Resistances to alkalis, organic acids, inorganic acids, gases, oils, solvents, oxidizing agents are described as are properties related to aging, abrasion and flame resistance, hardness, high and low temperature properties, weather and ozone resistance, toxicity, color and odor, adhesion.

A table of over 200 corrosives is given against which hard and soft rubber are rated. Control ratings are given also for butyl, nitrile and chloroprene rubbers. 5.4.3

Foreword

COMMITTEE T-6A was organized for the purpose of collecting and disseminating to the corrosion engineer factual and qualitative data on performance or limitations of organic materials successfully used in coatings and linings. While every attempt is made to be factual in the coverage of application in chemical resistance tables and physical properties, it nevertheless should be recognized that changes in compounding formulations of organic materials for coatings or linings enhance or detract from their corrosion-resistance. Under these circumstances, these reports and recommendation lists must be viewed as showing average properties only. The possibilities of changes in chemical and physical characteristics of materials produced by various manufacturers or applicators should be kept in mind.

Definition

This report is concerned with hard and soft rubber linings of ⅛ inch minimum thickness, for tanks, pipes, fittings, valves and auxiliary equipment. Also, it is specifically aimed at, and outlines, applications for natural rubber linings (hard, semi-hard and soft). Information on neoprene (CR), butyl (IIR), and acrylonitrile-butadiene (NBR) compounded materials is included in the chemical resistance tables for comparison purposes only. (See notes at end of tabulated data).

Summary of Properties and Uses

Materials referred to are compounded, dense, calendered sheet, (⅛ inch minimum thickness) which have been cemented to previously prepared sandblasted steel, cast iron or other metallic substrates, and then cured. In lining a contoured surface (pipe, fittings, etc.), the calendered sheet is precut, following a template, to the proper shape and the edges skived. This precut, uncured sheet, or "pattern" is then applied with adhesive to the substrate and the skived edges overlapped and knitted or rolled by hand. When the object being lined has been prepared in this manner, it is placed in a vulcanizer and cured for the recommended time and temperature. The rubber-lined equipment is then withdrawn and cooled and the surface carefully examined for imperfections, holidays or blisters. The seams may be partially ground or sanded for smooth contour, or allowed to remain as vulcanized. The equipment is then tested electrostatically or electrolytically, to be certain that the lining is free of holidays.

Over the years, the rubber industry has developed a standard lining practice, which is closely followed by appliers. Equipment to be rubber lined should be designed with lining in mind. Large or odd shaped equipment, whether fabricated or cast, should be sufficiently reinforced and adequately stable to resist movement or flexing and thus avoid separation of the lining due to its limited elasticity.

Hard Linings

Rubber linings may be hard, semi-hard or soft. Hard linings should be applied only to rigid pieces of limited size which are geometrically rigid. Hard rubber linings are often applied to pipe fittings and valves, where heavy cast sections adequately support the relatively "hard" material.

Semi-Hard Linings

The so-called "semi-hard" type of rubber lining is the most popular and the most generally used for application to chemical equipment. This material, in common with most types of rubber linings, consists of crude rubber, sulfur, rubber dust, accelerator, flux (plasticizer) and fillers of various types, relative amounts of which determine hardness and the degree of flexibility. Also, time and temperature of cure influences these properties. This "semi-hard" lining must, of necessity, have some flexibility to follow slight changes in tank contour as it is loaded and unloaded with fluid. Often the tank surface is covered with a cement and a thin soft rubber lining system, to which a semi-hard rubber tank lining is cemented, to give a "composite" lining. This enhances flexibility and avoids the use of higher percentages of plasticizer, which would increase the absorption tendency.

Soft Linings

Soft rubber linings have the greatest flexibility and accommodation to movement of underlying surfaces. They occasionally are placed over a semi-hard rubber lining, to form another type of composite, in chemical applications where the soft rubber surface is attacked initially to form a chemically inert surface and thus protect the semi-hard rubber underneath. Also, in crystallizers and similar equipment, where acid crystalline magmas are handled, soft rubber lining is placed in extra thicknesses over nozzle openings, scraped or velocity areas, or wherever abrasion resistance as well as acid resistance is needed.

Success with rubber linings—as with any organic lining—depends on thorough design detail and understanding of mechanical and chemical effects that will take place during the life of the equipment. In some areas where heavy bearing loads may be experienced, semi-hard

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linings can be thicker, or in areas where abrasion resistance is required, they can be covered with a soft rubber especially compounded for chemical and abrasion resistance. The extent of compression set or thinning of linings under a concentrated load should be taken into consideration, to avoid cutting or cracking.

Compounding

There are so many combinations and types of so-called "hard" or "semi-hard" rubber linings it is impossible to cover them in detail in this report. Many applicators, through custom, experience and preference, have their own types of compounds which are recommended for specific chemical applications. Old and even modern terminology in some cases often is inadequate or only semi-descriptive, so some confusion may arise in the specification and application of many types of compounded rubber linings. For example, the word "ebonite" is used, occasionally, as a description or implication with reference to a semi-hard rubber lining, to imply the chemical resistance of "ebonite."

Function of Compound

To make the application of rubber practical, and to take advantage of the actual chemical resistance of the composition of sulfur and rubber, the compound is modified with a greater proportion of the rubber hydrocarbon and a lesser proportion of sulfur (minimum of 15 percent sulfur). This is mixed with acid-resisting fillers, rubber dust, accelerator and limited flux or plasticizers; to produce a workable mass that can be kneaded, extruded or calendered, and applied in the raw state to the metal surface. Curing of this compound in a vulcanizer promotes the final chemical reaction between the unsaturated rubber hydrocarbon, sulfur and other reagents. Vulcanization produces a compound that achieves its chemical resistance by the inertness of the rubber hydrocarbon-sulfur bond. This inertness is enchanced by chemically resistant fillers added to the material.

Rubber hydrocarbon containing 1 to 5 percent sulfur with the usual compounding ingredients, produces a "soft" lining with considerable elongation and extensibility, approximating that of a gum rubber sheet, when cured or vulcanized. In some cases, this material can be filled with chemically inert materials to increase over-all inertness.

Normally, hard or semi-hard rubber linings are measuerd for hardness on the Shore "D" scale of relative hardness, and soft linings are measured for hardness on the Shore "A" scale. For example, hard rubber linings for typical chemical equipment measure from 55 to 75 on the Shore "D" scale, and soft linings measure from 55 to 90 on the Shore "A" scale.

Fillers Must Be Inert

To promote the inherent chemical resistance of the natural rubber-sulfur composition, only chemically inert fillers can be utilized. Acid sensitive fillers cannot be used because they would increase acid sensitivity, percentage of swell, and promote the loss of physical properties. This would result in an inadequate rubber lining for chemical service. It is impossible to use silica-rich fillers in a lining designed for resistance to hydrofluoric acid because the acid would permeate and attack the fillers. This would lead to loss in physical properties, increased absorption and lining disintegration.

Many modifications and different methods are used in making linings or coatings of rubber that can be called rubber linings. For example, rubber-covered surfaces can be produced by electrolytic deposition from a specially compounded latex bath. The bath is accelerated so that the rubber-covered surface vulcanizes autocatalytically. Ultra-accelerated latexes often are painted or brushed on as protective coatings. An example of this is rubber-base paints, which are outside the scope of this report.

Chemical Resistance by Service Classification

Alkalies

Hard rubber lining usually are both acid and alkali resistant, so ordinary semi-hard rubber lining compounds can withstand sodium or potassium hydroxide solutions up to 150 F. Highly concentrated and hot caustic solutions may have some effect, depending upon what ingredients have been incorporated into the lining. Also, the lining in this case would tend to swell slightly and to "throw" color or leach until the colored solubles have been removed. Ordinarily, hard rubber lining compounds are resistant to moderate concentrations of sodium hydroxide, potassium hydroxide, ammonium hydroxide, etc.

Inorganic Acids

The ordinary hard rubber lining compound is satisfactory for use up to and including 50 percent sulfuric acid at temperatures up to 150 F. Concentrated sulfuric acid has a very detrimental action on soft and hard rubber linings and in contact with 98 percent sulfuric acid, or higher concentrations (oleum-fuming), they will sulfonate, swell and char.

Hard rubber lining compounds are very resistant to sulfuric acid salts, such as alum, sodium bisulphate or sodium bisulphite. They resist sulfurous acid, but soft rubber linings will not. Hard rubber linings also are resistant up to and including fuming hydrochloric acid, when properly compounded, but are not resistant to nitric or chromic acids except under limited circumstances, where there may be a few hundred parts per million of free nitric or chromic radical and for short exposures at room temperature.

Organic Acids

Hard rubber linings are chemically resistant, when properly compounded, to moderate concentrations of formic, acetic, propionic and butyric acids. However, when anhydrous organic acids are involved, such as glacial acetic acid, it has a marginal application and increased swelling and deterioration will be experienced. A small volume of water greatly reduces the swelling and chemical attack. They are attacked only slowly by fatty acids, so they have been used in some types of equipment in which they are exposed to fatty acids and to an acid wash.

Gases

Hard rubber linings are not affected by dry or wet oxygen, carbon dioxide or nitrogen. When properly compounded, they are satisfactorily resistant to wet chlorine and have found wide application in chlorine-producing equipment. They are not resistant to dry chlorine and it is essential that saturating moisture always be present if chlorine vapor is present. Hard rubber linings are resistant to hydrogen sulfide, sulfur dioxide, and sulfur trioxide, preferably in the presence of moisture.

Soft rubber linings are easily permeated and absorb sulfur dioxide and/or sulfur trioxide and hydrogen sulfide, resulting in attack and deterioration. Wet or dry ammonia has little effect on hard rubber compounds, which are also resistant to solutions of iodine, but not resistant to liquid bromine or bromine vapors. Hard rubber linings are not affected by gaseous acetylene, propane, butane, methane, etc., but they are not normally used to handle these materials.

Oils

Animal and vegetable and mineral oils have very little effect on hard rubber compounds that have been satisfactorily compounded for resistance to them. Hydrocarbon or mineral oils also have limited effect on hard rubber lining compounds specifically compounded to resist swelling and permeation, when alternately exposed to acid conditions as well. However, new oil-resistant elastomeric materials have supplanted hard rubber lining compounds in this application. Before oil-resistant elastomeric linings or compounds were available much work was done in Europe to produce satisfactory oil-resisting rubber linings.

Solvents

The application of hard rubber linings is limited in solvent services and only simple aliphatic alcohols or ketones can be handled, where absolutely necessary. Usually, ethyl alcohol or acetone, for example, have little effect, although a certain amount of leachables are removed, and this tends to cause shrinkage. Chlorinated solvents, higher molecular weight ketones, ethers, esters and nitroparaffin compounds are not satisfactorily handled.

Oxidizing Agents

Chlorine dioxide has some effect on hard rubber lining, but it is usable, if necessary. However, other construction materials are available with more resistance to chlorine dioxide. While wet chlorine can be handled by hard rubber linings, hydrogen peroxide, except in very dilute concentrations, can not, nor

can nitric or chromic acid in appreciable concentrations. Permanganates and persulfates also have a deleterious effect, and sodium hypochlorite is sporadically destructive. Improperly compounded or improperly cured hard rubber linings can fail quickly while a properly compounded and applied lining may be satisfactory for a number of years in contact with sodium hypochlorite.

Properties of Rubber Linings (Hard and Soft)

Aging

Hard and semi-hard rubber linings have excellent aging properties. A qualified lining would not be expected to fail precipitously due to aging, but soft rubber is more susceptible to deterioration by aging, so this should be taken into account when considering it. When the lining is submerged and protected from heat and oxidizers aging is minimized.

Impact resistance of both semi-hard and soft rubber linings is satisfactory. They are rarely fractured when subjected to impact in industrial applications. However, if the shock or impact is severe and lining deflection excessive, failure by cracking or chipping may occur. This is kept in mind by the applicator, so normally it is not necessary to specify impact resistance.

Abrasion Resistance

Semi-hard or hard rubber linings are not abrasion resistant. They will be abraded by suspended materials in the fluid being handled, particularly in areas where fluid velocity is relatively high. For example, in fluids containing suspensions, the change of direction of flow —such as in an elbow or around a tank nozzle—may quickly result in the thinning and puncturing. For this reason, if abrasion is to be encountered, soft rubber linings pads are indicated. If this is done, then their reduced chemical and heat resistance must be taken into consideration, because it is impossible to obtain the acme of abrasion, chemical and temperature resistance and a balance of desirable physical properties, all in one compound.

Electrical Properties

Hard rubber lining compounds are non-conductors and have adequate dielectric strength. It is possible to add such materials as graphite to them to make them semi-conducting. If electrical properties are important, then the solution should be worked out with the compounder and applicator.

Flame Resistance

Neither hard nor soft rubber linings are flame resistant. It is possible to improve this property somewhat by compounding, so that exposure to flame will char the surface only, but this is of short-term value.

Hardness

All rubber linings can be made in a wide variety of hardness ranges. The choice of hardness must take into consideration the application of the lining, the construction and use of the chemical equipment, the temperature involved, the abrasive resistance required, and the amount of flexibility desired. All other factors being equal, the harder the compound the more chemically resistant.

Abbreviations Used in the Following Table

Low Mol. Wt.	Low Molecular Weight
Alk. Sol.	Alkali Solution
Aq.	Aqueous
Sol.	Solution
Act.	Active
RT	Room Temperature
Proc.	Process
Nat.	Natural
Neut.	Neutral
Med. Conc.	Medium Concentration
Conc.	Concentration
Sat.	Saturated
Cont.	Containing
Disp.	Dispersion

Ratings of Rubber Linings vs Corrosives

LEGEND:[3]

R—Recommended. Good service can be expected.

LR—Limited Recommendation. Good service may be expected under some conditions, such as intermittent exposure for short periods. Service testing is advisable.

NR—Not Recommended. Service likely to be too poor to warrant use, or insufficient data available to permit more favorable rating. Adequate service often may be obtained under special conditions. Service testing suggested.

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Acetaldehyde—100%	NR	LR	LR	NR	NR
Acetaldehyde—40%	NR	R	R	LR	LR
Acetate Solvents (Crude)	NR	LR	LR	LR	LR
Acetate Solvents (Pure)	NR	NR	NR	NR	NR
Acetic Acid—to—20%—30%	LR	R	LR	LR	LR
Acetic Acid (80%)	NR	LR	NR	NR	NR
Acetic Acid (Glacial)	NR	LR	NR	NR	NR
Acetone	LR	LR	R	NR	LR
Acetyl Chloride	NR	NR	NR	NR	NR
Acetamide	NR	R	LR	LR	LR
Acid Water	R	R	R	R	R
Activated Alumina (Abrasive)	LR	NR	LR	LR	LR
Activated Silica	R	R	R	R	R
Activated Sludge	LR	R	LR	R	R
Alcohol-amyl	NR	LR	LR	LR	LR
Alcohol-Butyl	NR	R	R	R	R
Alcohol-Ethyl	R	R	R	R	R
Alcoholic Drinks (Taste-Odor)	..	..	R	R	R
Allyl Chloride	NR	NR	NR	NR	NR
Alphatic Hydrocarbons	NR	LR	NR	LR	LR
Alum-Ammonium	R	R	R	R	R
Alum-Chrome	R	R	R	R	R
Aluminum Acetate	R	R	R	R	R
Aluminum Chloride	R	R	R	R	R
Aluminum Fluoride	R	R	R	R	R
Aluminum Hydroxide	R	R	R	R	R
Aluminum Nitrate (Neutral)	...	R	R	R	R
Aluminum Sulfate	R	R	R	R	R
Amines (Low Mol. Wt.)	NR	R	R	LR	R
Ammonia Aqueous Solutions	R	R	R	R	R
Ammonia-Gas (Dry)	...	...	R	R	R
Ammonia-Liquid	R	R	R	R	R
Ammoniated Brine	R	R	R	R	R
Ammonium Acetate	R	R	R	R	R
Ammonium Bicarbonate	R	R	R	R	R
Ammonium Bifluoride	R	R	R	R	R
Ammonium Bromide (Neutral)	...	R	R	...	R
Ammonium Carbonate	R	R	R	R	R
Ammonium Chloride	R	R	R	R	R
Ammonium Fluoride	R	R	R	R	R
Ammonium Fluosilicate	R	R	R	R	R
Ammonium Formate	...	R	R	R	R
Ammonium Hydrosulfide	...	R	R	R	R
Ammonium Hydrosulfite	LR	R	R	R	LR
Ammonium Hydroxide	R	R	R	R	R
Ammonium Metaphosphate	R	R	R	R	R
Ammonium Nitrate (Neutral)	...	R	R	R	R
Ammonium Oxalate	R	R	R	R	R
Ammonium Picrate	...	R	R	R	R
Ammonium Phosphate (Acid)	R	R	R	R	R
Ammonium Phosphate (Neutral)	R	R	R	R	R
Ammonium Persulfate	NR	R	LR	LR	LR
Ammonium Sulfate	R	R	R	R	R
Ammonium Sulfide	NR	R	LR	LR	LR
Ammonium Thiocyanate	R	R	R	R	R
Amyl Acetate	NR	NR	NR	NR	LR
Amyl Chloride	NR	NR	NR	NR	NR
Aniline	NR	LR	LR	NR	LR
Aniline Hydrochloride Sol.	LR	R	R	...	LR
Anodizing Bath-Alk. Sol.	R	R	R	R	R
Anthraquinone Sulfonic Acid-Aq.	...	R	R	R	R
Antimony Acid Salts	R	R	R	R	R
Antimony Trichloride Sol.	R	R	R	R	R
Aqua Regia (Dilute)	NR	NR	LR	NR	NR
Aqua Regia (Concentrated)	NR	NR	NR	NR	NR

Heat Resistance

For maximum service, a semi-hard or soft rubber lining should not be used over temperatures of 150 F except for short periods. Temperatures of 200 to 230 F, while feasible with hard rubber lined equipment, should be for short-term exposure only. Extended heating, steaming out, or steam lancing has a detrimental effect on both semi-hard and soft rubber linings and is not recommended.

Low Temperature Properties

It is possible, through proper compounding, to enhance—to a very limited extent—low temperature properties of semi-hard and soft rubber linings. Thus, it is possible to obtain linings that will not be brittle or suffer from cracking or fracture in cold weather. If such a requirement must be met, special attention must be paid to compounding and to any other service requirements involved, so that a satisfactory lining will be produced. Low temperatures may cause increased brittleness in semi-hard rubber linings to the point where failure may occur on pressure or impact.

Weather and Ozone Resistance

Weather and ozone resistance of semi-hard rubber linings is adequate, but is marginal to poor on soft rubber linings, indicating the choice of other materials when this is a requirement.

Toxicity, Color and Odor

Semi-hard and soft rubber lining compositions can be produced free of mercury, lead, other heavy elements, and of other materials that can cause toxicity. Therefore, distilled water equipment, demineralizers for the processing of potable water and equipment of this type can be rubber lined. "Conditioning," soaking and flushing can eliminate contamination of high ohmic water. Also, it is possible to compound to avoid the throwing of color or adding even slight odor. This requires special compounds not normally used for industrial chemical applications.

Adhesion

Adhesion to the metal substrate is of paramount importance to prevent migration of corrosion behind the lining, if a breakthrough occurs. Also it is important in vacuum systems to prevent buckling or stripping. Good adhesion eliminates the pressure potential through the lining that increases permeation. An average acceptable adhesion value is 400 psi minimum on cast iron or steel—specific adhesion, for a well designed and cured lining/cement system. Adherence to aluminum would be about one-fourth of this value at room temperature, unless specifically compounded for higher adhesion.

Table of Chemical Resistance

A considerable number of industrial chemical resistances is listed for semi-hard or soft types, including some where they are not recommended. For comparison are shown over-all chemical resistance of neoprene, butyl and butadiene-acrylonitrile elastomers. It should be borne in mind that these charts are not specific recommendations but only general in nature.

When every facet of the service is taken into consideration, it is possible through proper compounding and production to produce a specific semi-hard or soft compound which will be of maximum utility. Inadequate compounding; carelessness and misapplication can result in failure of any of these linings, when improperly used or applied to equipment inadequately constructed; or exposed to a series of varying aggressive environments; excessive temperatures, stress-impact or solvent attack.

Maximum permissable temperature is 150 F., except as otherwise noted. This chart does not attempt to show comparisons at high temperatures and involving them should be worked out between the user and applicator at the time equipment is under consideration.

Ratings of Rubber Linings vs Corrosives, Cont'd.

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Aromatic Hydrocarbons	NR	NR	NR	LR	LR
Arsenic Acid	R	R	R	R	R
Arylsulfonic Acid-Aq.	R	R	R	R	R
Asphalt Emulsion	NR	NR	NR	LR	NR
Barium Chloride	R	R	R	R	R
Barium Hydroxide	R	R	R	R	R
Barium Sulfide	...	R	R	...	...
Battery Acid to 50%	R	R	R	R	R
Beer	...	...	R	...	R
Beet Sugar Liquors	R	R	R	R	R
Benzaldehyde (Acid Media)	NR	NR	NR	NR	NR
Benzene (Acid Media)	NR	NR	NR	LR	NR
Benzene Sulfonic Acid-Aq.	...	R	R	R	R
Benzene	NR	NR	NR	NR	NR
Benzoic Acid-Aq.	...	R	R	R	R
Beryllium Sulfate	R	R	R	R	R
Black Liquor (Sulfate)	NR	R	LR	R	LR
Bleach, Laundry (15% Act. Cl_2)	LR	R	R	LR	LR
Bonderite	LR	R	R	R	R
Borax	R	R	R	R	R
Boric Acid	R	R	R	R	R
Boron Trifluoride (Liquid)	...	NR	LR	NR	NR
Brine Solutions-R.T.	R	R	R	R	R
Bromic Acid	NR	NR	NR	NR	NR
Bromine (Liquid)	NR	NR	NR	NR	NR
Bromine (Water)	NR	NR	R	NR	LR
Buromin	R	R	R	R	R
Butanol (Primary)	NR	R	R	R	R
Butanol (Secondary)	NR	R	R	R	R
Butyl Acetate	NR	NR	LR	NR	NR
Butyl Alcohol	NR	R	R	R	R
Butyl Phenol	NR	NR	LR	NR	LR
Butyl Cellosolve	NR	LR	LR	LR	LR
Butyl Lactate	NR	LR	LR	NR	NR
Butyric Acid Liquor	NR	LR	LR	LR	NR
Cadmium Chloride	R	R	R	R	R
Calcium Bisulfite	LR	R	R	LR	LR
Calcium Chlorate	NR	LR	R	LR	LR
Calcium Chloride	R	R	R	R	R
Calcium Hydroxide	R	R	R	R	R
Calcium Hypochlorite	R	R	R	R	LR

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Calcium Nitrate	R	R	R	R	R
Cane Sugar Liquors	...	R	R	R	R
Carbolic Acid (Phenol)-Aq.	NR	R	R	NR	LR
Carbon Bisulfide	NR	NR	NR	NR	NR
Carbon Dioxide (Wet)	R	R	R	R	R
Carbon Dioxide (Dry)	R	R	R	R	R
Carbon Tetrachloride	NR	NR	NR	NR	NR
Carbonic Acid	R	R	R	R	R
Casein Water Paint	...	R	R	R	R
Castor Oil	R	R	R	R	R
Caustic Soda (All)	LR	R	R	R	R
Caustic Potash (All)	LR	R	R	R	R
Cellosolve	NR	LR	LR	LR	LR
Chloracetic Acid-Aq.	NR	R	R	LR	LR
Chloral Hydrate-Aq.	NR	R	R	LR	LR
Chloramine	NR	R	R	R	R
Chlorinated Water	LR	R	R	R	R
Chloric Acid	NR	LR	R	LR	LR
Chlorine Dioxide	NR	R	R	LR	LR
Chlorine Gas (Dry)	NR	NR	NR	NR	NR
Chlorine Gas (Wet)	LR	R	R	NR	NR
Chlorine Water	LR	R	R	NR	NR
Chlorobenzene (Mono)	NR	NR	NR	NR	NR
Chloroform	NR	NR	NR	NR	NR
Chlorophyll-Aq.	R	R	R	R	R
Chlorosulfonic Acid-Aq.	NR	R	R	R	R
Chrome Acid Cleaning Solution	NR	NR	LR	NR	NR
Chrome Alum	R	R	LR	R	R
Chrome Liquor	NR	NR	LR	NR	NR
Chrome Plating Bath	NR	NR	LR	NR	NR
Chromic Acid (All)	NR	NR	LR	NR	NR
Chromium Chloride	NR	NR	LR	NR	NR
Chromium Chloride	NR	NR	LR	NR	NR
Citric Acid	LR	R	R	R	R
Cocoanut Oil	NR	LR	NR	R	NR
Cooking Oil	NR	NR	NR	LR	NR
Copper Chloride	R	R	R	R	R
Copper Cyanide	R	R	R	R	R
Copper Nitrate	NR	NR	R	NR	NR
Copper Plating (Acid Proc.)	R	R	R	R	R
Copper Plating (Alkaline Proc.)	R	R	R	R	R
Copper Sulfate	R	R	R	R	R

Ratings of Rubber Linings vs Corrosives, Cont'd.

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Core Oils	NR	NR	NR	R	NR
Corn Oils	NR	LR	NR	R	NR
Cottonseed Oil	NR	LR	NR	R	LR
Corn Syrup	R	R	R	R	R
Cresol	NR	LR	LR	NR	LR
Cresylic Acid (50%)	NR	LR	LR	NR	LR
Crude Oil (Sour)	NR	LR	NR	LR	LR
Crude Oil (Sweet)	NR	LR	NR	LR	LR
Cyanide Plating Solutions	R	R	R	R	R
Cyclohexanol	NR	LR	LR	LR	LR
Cyclohexanone	NR	NR	NR	NR	NR
Deionized Water[7]	R	R	R	R	R
Demineralized Water[7]	R	R	R	R	R
Developer-Photo	R	R	R	R	R
Dextrose	R	R	R	R	R
Diammonium Phosphate	R	R	R	R	R
Diazo Salts	NR	NR	LR	NR	NR
Dichloromethane	NR	NR	NR	NR	NR
Diethylene Glycol	R	R	R	R	R
Diglycolic Acid	LR	R	R	R	R
Dimethylamine	LR	R	R	R	R
Dioctyl-phthalate-Ertrained-Aq	NR	LR	LR	NR	NR
Disodium Phosphate	R	R	R	R	R
Distilled Water[7]	R	R	R	R	R
Edible Oils	NR	LR	LR	R	LR
Ethers-Low Mol. Wt.	NR	NR	NR	NR	NR
Ethyl Acetate	NR	LR	LR	NR	NR
Ethyl Alcohol	R	R	R	R	R
Ethyl Chloride	NR	NR	NR	NR	NR
Ethyl Ether	NR	NR	NR	NR	NR
Ethylene Bromide	NR	NR	NR	NR	NR
Ethylene Chloride	NR	NR	NR	NR	NR
Ethylene Chlorhydrin	NR	NR	NR	NR	NR
Ethylene Dichloride	NR	NR	NR	NR	NR
Ethylene Glycol	R	R	R	R	R
Ethylene Oxide-(Mixed Aq. Phase)	NR	LR	NR	LR	LR
Fatty Acids	NR	LR	NR	R	LR
Ferric Chloride	R	R	R	R	R
Ferric Nitrate	LR	R	R	R	R
Ferric Sulfate	R	R	R	R	R
Ferrous Chloride	R	R	R	R	LR
Ferrous Oxalate	R	R	R	R	R
Ferrous Sulfate	R	R	R	R	R
Fish Solubles	NR	LR	NR	R	LR
Flavoring Syrups	...	...	R	R	R
Fluoride Salts-Aq.	R	R	R	R	R
Fluorine Gas (Wet)	NR	LR	LR	NR	LR
Fluorine Gas (Dry)	NR	NR	NR	NR	NR
Fluoborate Salts	R	R	R	R	R
Fluboric Acid	R	R	R	R	R
Fluosilicic Acid & Salts	R	R	R	R	R
Foam Latex Mix. Nat.	R	R	R	R	R
Formaldehyde—40%	LR	R	R	R	R
Formic Acid	LR	R	R	R	R
Freon (Wet) Low Pressure System	NR	LR	LR	LR	LR
Freon (Dry) Low Pressure System	NR	...	LR	LR	LR
Fructose	R	R	R	R	R
Fruit Juices (Pulp)	...	R	...	R	...
Fuel Oil (Cont. Hydrogen Sulfide)	NR	NR	NR	NR	NR
Furfural	LR	R	LR	NR	LR
Gallic Acid	R	R	R	R	R
Gallium Sulfate	R	R	R	R	R
Gas (Coke Oven) Wet, Acid	...	LR	NR	LR	NR
Gas Natural (Wet)	NR	LR	NR	LR	NR
Gas Manufactured Wet	NR	LR	NR	LR	NR
Gasoline (Sour)	NR	NR	NR	LR	LR
Gasoline (Refined)	NR	NR	NR	R	R
Gelatine	R	R	R	R	R
Glucose	R	R	R	R	R
Gluconic Acid	LR	R	R	R	R
Glue	R	R	R	R	R
Glutamic Acid	LR	R	R	R	R
Glycerine	R	R	R	R	R
Glycine	LR	R	R	R	R
Glycine Hydrochloride	R	R	R	R	R
Glycolic Acid	LR	R	R	R	R
Glycols	R	R	R	R	R
Gold Chloride	R	R	R	R	R
Gold Cyanide	R	R	R	R	R
Green Liquor (Paper Industry)	R	R	R	R	R
Gluten	R	R	R	R	R
Grease	NR	NR	NR	R	LR
Hexanol, Tertiary	R	R	R	LR	LR
HTH	R	R	R	LR	LR
Hydrobromic Acid	NR	LR	LR	LR	LR
Hydrocarbons (Aliphatic. See Class)	NR	NR	NR	R	R
Hydrocarbons (Aromatic. See Class)	NR	NR	NR	LR	NR
Hydrochloric Acid (Muriatic)	R	R	R	R	LR

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Hydrochloric (50/50 Hydrofluoric)	LR	R	R	LR	LR
Hydrocyanic Acid	R	R	R	R	R
Hydrogen Cyanide	R	R	R	R	R
Hydrogen Phosphide	LR	R	R	LR	LR
Hydrofluoric Acid	LR	R	R	LR	LR
Hydrofluosilicic Acid	R	R	R	R	R
Hydrogen	...	...	R	R	R
Hydrogen Peroxide (30 Vol.)	NR	LR	R	NR	R
Hydrogen Sulfide (Dry)	...	...	R	R	R
Hydroquinone-Aq.	...	R	R	R	R
Hydroxylamine Sulfate	R	R	R	R	R
Hypo (Sodium Thiosulfate)	R	R	R	R	R
Hypochlorite Sodium	LR	R	R	LR	LR
Hypochlorous Acid	LR	R	LR	LR	NR
Ink	LR	R	R	R	R
Iodine Solution	LR	R	R	R	R
Kerosene	NR	NR	NR	R	LR
Kraft Liquor (Paper Industry)	LR	R	R	R	R
Lacquers	NR	NR	NR	NR	NR
Lacquer Solvents	NR	NR	NR	NR	NR
Lactic Acid/Lactose	R	R	R	R	R
Lard Oil	NR	LR	NR	R	LR
Lauric Acid	NR	LR	NR	R	LR
Lauryl Chloride	NR	NR	NR	LR	NR
Lauryl Sulfate (Neutral Salt)	...	R	R	R	R
Lead Acetate	R	R	R	R	R
Lime Slaked	R	R	R	R	R
Linoleic Acid	NR	LR	NR	R	LR
Linseed Oil	NR	LR	NR	R	LR
Liquers-Potable	...	...	R	...	R
Lubricating Oil No. 1	NR	LR	NR	R	LR
Magnesium Bisulfite	LR	R	R	LR	LR
Magnesium Chloride	R	R	R	R	R
Magnesium Hydroxide	R	R	R	R	R
Magnesium Nitrate	R	R	R	R	R
Magnesium Sulfate	R	R	R	R	R
Malic Acid-Aq.	LR	R	LR	R	R
Maleic Acid-Aq.	LR	R	R	R	R
Manganese Chloride	R	R	R	R	LR
Manganese Sulfate	R	R	R	R	R
Melamine Resin-(Hydrochloride)	R	R	R	R	LR
Mercuric Chloride	R	R	R	R	R
Mercuric Cyanide	R	R	R	R	R
Mercuric Nitrate (Neutral)	LR	R	R	R	R
Mercurous Nitrate (Acid)	NR	NR	R	NR	NR
Mercury	R	R	R	R	R
Methanol (Methyl Alcohol)	R	R	R	R	R
Methyl Chloride	NR	NR	NR	NR	NR
Methyl Ethyl Ketone	LR	R	LR	NR	R
Methyl Sulfate sulfuric acid Aq.	NR	R	R	LR	R
Methylene Chloride	NR	NR	NR	NR	NR
Milk	...	...	...	R	...
Mineral Oils	NR	LR	NR	R	R
Mixed Acid 40% Sulfuric/15% Nitric	NR	NR	LR	NR	NR
Molasses	R	R	R	R	R
Muriatic Acid (Hydrochloric)	R	R	R	R	LR
Naphtha (in sulfuric acid)	NR	NR	NR	LR	NR
Naphthalene (in sulfuric acid)	NR	NR	NR	LR	NR
Nickel Acetate	R	R	R	R	R
Nickel Chloride	R	R	R	R	R
Nickel Nitrate (Neutral)	R	R	R	R	R
Nickel Sulfate	R	R	R	R	R
Nicotine	NR	R	NR	LR	LR
Nicotinic Acid	NR	R	NR	LR	LR
Nitric Acid Anhydrous	NR	NR	NR	NR	NR
Nitric Acid (Dilute)	NR	NR	R	NR	NR
Nitric Acid (Concentrated)	NR	NR	NR	NR	NR
Nitric Acid (Fuming)	NR	NR	NR	NR	NR
Nitrobenzene	NR	LR	LR	NR	NR
Nitrogen Solutions	R	R	R	R	R
Nitroglycerine (Neutral)	R	R	R	R	R
Oil—Castor	R	R	R	R	R
Oil—Cocoanut	NR	LR	NR	R	LR
Oil—Corn	NR	LR	LR	R	LR
Oil—Creosote	NR	NR	NR	NR	LR
Oil—Sour Crude	NR	LR	NR	R	R
Oil (ASTM No. 1, 2 or 3)	NR	LR	NR	R	R
Oils and Fats	NR	NR	NR	R	LR
Oleic Acid	NR	LR	LR	R	LR
Oleum	NR	NR	NR	NR	NR
Oxalic Acid	R	R	R	R	R
Oxygen	...	...	...	R	R
Ozone	NR	LR	LR	LR	LR

Ratings of Rubber Linings vs Corrosives, Cont'd.

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	RUBBER Hard[1]	IIR[1]	NBR[1]	CR[1]
Paint–Water Base	...	R	R	R	R
Palmitic Acid	NR	LR	LR	R	LR
Paper Stock Acid/Alk.	R	R	R	R	R
Pectin Solution Acid	R	R	R	R	R
Pentaerythritol Sol.	R	R	R	R	R
Perchloric Acid (Dilute)	NR	LR	LR	LR	LR
Perochlorethylene	NR	NR	NR	NR	NR
Permanganic Acid	NR	LR	R	LR	LR
Peroxide Bleach	R	R	R	LR	LR
Persulfuric Acid (Dilute)	NR	LR	R	LR	LR
Petroleum (Crude)	NR	LR	NR	R	R
Phenol (Carbolic Acid)	LR	R	R	NR	LR
Phenyhydrazine Hydrochloride	LR	R	R	R	LR
Phosgene (Gas)-Wet	NR	R	LR	LR	LR
Phosphoric Acid (Dilute)	R	R	R	R	R
Phosphoric Acid (Med. Conc.)	R	R	R	R	R
Phosphoric Acid (Conc.)	R	R	R	R	R
Phosphorus (Yellow)-Wet	NR	LR	LR	...	LR
Phosphorus Pentoxide-Wet	LR	R	R	...	R
Phosphorus Trichloride	NR	LR	LR	NR	NR
Photographic Solutions (Developer)	R	R	R	R	R
Pickle Brine	R	R	R	R	R
Pickling Acid (Sulfuric)	R	R	R	R	R
Picric Acid	LR	R	R	R	R
Plating Solutions–General	R	R	R	R	R
Polyvinyl Acetate Commercial Disp.	...	...	...	R	R
Potable Water	R	R	R	R	R
Potassium Acetate	R	R	R	R	R
Potassium Alum. Sulfate	R	R	R	R	R
Potassium Bicarbonate	R	R	R	R	R
Potassium Bichromate	NR	NR	R	LR	LR
Potassium Borate	R	R	R	R	R
Potassium Bromate	LR	LR	R	R	R
Potassium Bromide	R	R	R	R	R
Potassium Carbonate	R	R	R	R	R
Potassium Chlorate	LR	LR	R	LR	LR
Potassium Chloride	R	R	R	R	R
Potassium Chromate (Neutral)	R	R	R	R	R
Potassium Cyanide	R	R	R	R	R
Potassium Dichromate	NR	NR	R	LR	LR
Potassium Ferricyanide	R	R	R	R	R
Potassium Ferrocyanide	R	R	R	R	R
Potassium Fluoride	R	R	R	R	R
Potassium Hydroxide	R	R	R	R	R
Potassium Iodide	R	R	R	R	R
Potassium Nitrate	R	R	R	R	R
Potassium Perborate	LR	R	R	R	R
Potassium Perchlorate	NR	LR	R	LR	LR
Potassium Permanganate	LR	R	R	R	R
Potassium Persulfate	NR	LR	R	LR	LR
Potassium Phosphate	R	R	R	R	R
Potassium Sulfate	R	R	R	R	R
Potassium Xanthate	LR	R	LR	R	R
Propyl Alcohol	LR	R	R	R	R
Propylene Dichloride	NR	NR	NR	NR	NR
Pyrogallic Acid	LR	R	R	R	R
Pyromellitic Acid–Aq.	LR	R	R	R	R
Quatenary Ammonium–Aq.	R	R	R	R	R
Quebracho Tannin	R	R	R	R	R
Rayon Acid Water	LR	R	LR	R	R
Rayon Spin Bath	NR	R	LR	R	LR
River Water	R	R	R	R	R
Salicylic Acid-Aq.	LR	R	R	R	R
Saline Solutions	R	R	R	R	R
Salt Brine	R	R	R	R	R
Salt Brine Alkaline	R	R	R	R	R
Salt Brine Chlorine Sat.	LR	R	LR	LR	LR
Salt Brine Electrolytic	LR	R	LR	LR	LR
Salt Brine Pickling	R	R	R	R	R
Sea Water	R	R	R	R	R
Selenic Acid	R	R	R	R	R
Silver Cyanide	R	R	R	R	R
Silver Nitrate	R	R	R	R	R
Silver Plating Solutions	R	R	R	R	R
Soap Solutions	R	R	R	R	R
Sodium Acetate	R	R	R	R	R
Sodium Acid Fluoride	LR	R	R	LR	R
Sodium Aluminate	R	R	R	R	R
Sodium Arsenate	R	R	R	R	R
Sodium Benzoate	LR	R	R	R	R
Sodium Bichromate	LR	R	R	LR	LR
Sodium Bicarbonate	R	R	R	R	R
Sodium Bisulfate	R	R	R	R	R
Sodium Bisulfite	LR	R	R	LR	LR
Sodium Bromide	R	R	R	R	R
Sodium Carbonate	R	R	R	R	R
Sodium Chlorate	LR	R	R	LR	LR
Sodium Chloride	R	R	R	R	R
Sodium Chlorite	LR	R	R	LR	LR

CORROSIVE[2]	MATERIALS: RUBBER Soft[1]	RUBBER Hard[1]	IIR[1]	NBR[1]	CR[1]
Sodium Chromate (Neutral)	R	R	R	R	R
Sodium Cyanide	R	R	R	R	R
Sodium Dichromate	NR	LR	R	NR	NR
Sodium Ferricyanide	R	R	R	R	R
Sodium Ferrocyanide	R	R	R	R	R
Sodium Fluoride	R	R	R	R	R
Sodium Hydrogen Sulfate	R	R	R	R	R
Sodium Hydrosulfide	LR	R	R	R	R
Sodium Hydrosulfite	LR	R	R	LR	LR
Sodium Hydroxide	R	R	R	R	R
Sodium Hypochlorite	LR	R	R	LR	LR
Sodium Nitrate	R	R	R	R	R
Sodium Nitrite	R	R	R	R	R
Sodium Perborate	LR	R	R	R	R
Sodium Perchlorate	NR	LR	R	LR	LR
Sodium Peroxide	NR	R	R	R	R
Sodium Potassium Chloride	R	R	R	R	R
Sodium Phosphate (Acid)	R	R	R	R	R
Sodium Silica Fluoride	R	R	R	R	R
Sodium Silicate	R	R	R	R	R
Sodium Sulfate	R	R	R	R	R
Sodium Sulfide	LR	R	R	R	R
Sodium Sulfite	R	R	R	R	R
Sodium Thiocyanate	R	R	R	R	R
Sodium Thiosulfate	LR	R	R	R	LR
Sorbitol	R	R	R	R	R
Spensol Solution (Ammonia Fertilizer Sol.)	R	R	R	R	R
Stannic Chloride	R	R	R	R	LR
Stannous Chloride	R	R	R	R	LR
Starch Syrup	R	R	R	R	R
Stearic Acid	NR	LR	LR	R	LR
Steep Water	NR	R	LR	LR	LR
Stoddards Solvent	NR	NR	NR	NR	NR
Sugar-Ion Exchange	R	R	R	R	R
Sodium Sulfhydrate	R	R	R	R	R
Sugar Solutions	R	R	R	R	R
Sulfamic Acid	R	R	R	R	R
Sulfite Liquor	NR	R	LR	R	LR
Sulfur Dioxide Gas (Wet)	NR	R	LR	LR	LR
Sulfur Trioxide Gas (Wet)	NR	R	LR	LR	LR
Sulfuric Acid 50% (100 F)	LR	R	R	R	R
Sulfuric Acid—79%	NR	NR	LR	NR	LR
Sulfuric Acid—98%	NR	NR	NR	NR	NR
Sulfuric Acid 48% Nitric Acid 49%	NR	NR	NR	NR	NR
Sulfurous Acid (70 F)	NR	R	LR	LR	LR
Syntan (Synthetic Tannin)	LR	R	R	R	R
Tannic Acid	R	R	R	R	R
Tannin	R	R	R	R	R
Tanning Liquors	LR	R	LR	R	R
Tartaric Acid	R	R	R	R	R
Tetrahydrofurane	NR	NR	NR	NR	NR
Textile Dyeing	LR	R	LR	LR	LR
Thioglycolic Acid	LR	R	R	R	R
Thionyl Chloride	NR	NR	NR	NR	NR
Thiourea	LR	R	R	R	R
Tin Salts	R	R	R	R	R
Titanium Tetrachloride	NR	NR	LR	NR	NR
Toluene	NR	NR	NR	NR	NR
Tributyl Phosphate	NR	NR	NR	NR	NR
Trichloroethylene	NR	NR	NR	NR	NR
Tricresyl Phosphate	NR	NR	LR	NR	NR
Triethanolamine	LR	R	LR	R	R
Triethylamine	NR	LR	LR	LR	LR
Trichloracetic Acid	NR	LR	NR	NR	NR
Trisodium Phosphate	R	R	R	R	R
Tungstic Acid	R	R	R	R	R
Turpentine	NR	NR	NR	LR	NR
Unichrome Solu. Alkali	LR	R	R	R	R
Urea	R	R	R	R	R
Urea Ammonia Liquor	R	R	R	R	R
Varnish	NR	NR	NR	LR	NR
Vinegar	R	R	R	R	R
Vinyl Acetate Emulsion	NR	LR	LR	R	R
Vinyl Chloride Emulsion	NR	LR	LR	R	R
Water (Acid Mine Water)	R	R	R	R	R
Water (Acid Waste) Chloride	R	R	R	R	R
Water (Carbonated) Carbonic Acid	R	R	R	R	R
Water (Demineralized)[7]	R	R	R	R	R
Water–Desalted	R	R	R	R	R
Water–Distilled[7]	R	R	R	R	R
Water–Filtered	R	R	R	R	R
Water–Fresh	R	R	R	R	R
Water–Salt	R	R	R	R	R
Water–Saline	R	R	R	R	R
Wines	R	...	R	R	R
Whiskey	R	...	R	R	R
White Liquor	R	R	R	R	R
X-Ray Develop. Bath (Eastman)	R	R	R	R	R

Ratings of Rubber Linings vs Corrosives, Cont'd.

CORROSIVE[2]	MATERIALS				
	RUBBER				
	Soft[1]	Hard[1]	IIR[1]	NBR[1]	CR[1]
Xylene	NR	NR	NR	NR	NR
Yeast Liquor	LR	R	...	...	...
Zeolite Water	R	R	R	R	R
Zinc Acetate	R	R	R	R	R
Zinc Chloride	R	R	R	R	R
Zinc Cyanide	R	R	R	R	R
Zinc Cyanide	R	R	R	R	R
Zinc Nitrate	R	R	R	R	R
Zinc Sulfate	R	R	R	R	R

Notes:

(1) Codes for these types of linings are in accordance with the latest recommendation of the American Society for Testing Materials (ASTM-D 1418-60T), regarding nomenclature of rubber and elastomeric materials, I.E.;
Butyl Rubber—IIR (Isobutylene-Isoprene Polymer)
Nitrile Rubber—NBR (Acrylonitrile-Butadiene Polymer)
Chloroprene (Neoprene)—CR (Chloroprene Polymer)
Soft Rubber—(3-5% S)—90 Shore "A" or less
Hard Rubber—(15% or more sulphur) 75 Shore "D" or less

(2) Industrial processing seldom involves handing one simple or singular fluid. Rather, that process fluids usually are contaminated or advertently or inadvertently mixed with other fluids or ingredients. Hence, the problem is rarely one of meeting and combating attack from one fluid alone. Some reagents listed exist only in solution, or with excess acid present, or require some particular condition for stability. All of these, combined with temperature fluctuations, suspended solids, entrained fluids, etc., can modify or even reverse these listings. Under the circumstances, the user of these tables should be cognizant of the foregoing, analyze the service environment accurately, consult the equipment builder for assistance and pre-test or field test, if possible.

(3) The listings of: R—Recommended (No effect); LR—Limited recommended; NR—Not Recommended are based on published data and the experience of committee members. These ratings are relative only, and not to be blindly used by the uninitiated. It is not possible to condense the variations and vagaries of any one or combination of these chemical service environments to finality and prescribe an over-all solution to the problem of resisting corrosive attack in chemical environments such as those listed.
It should also be recognized that these relative ratings can be changed, one to another, depending on skill in compounding a base type stock to achieve maximum resistance inherent in the polymer.

(4) Concentrations for services listed are saturated, aqueous, unless otherwise noted.

(5) Ratings shown are to temperatures of 150 F maximum.

(6) Depending upon certain chemical reagents to which these linings are less resistant and more susceptible to permeation, ratings may change, particularly under the influence of temperature. Consequently, as in the case of rubber, the thickness of the lining should be correspondingly increased. A qualified rubber liner and/or equipment manufacturer should be consulted in all cases where there are any questions regarding serviceability, temperature resistance, thickness, etc.

(7) See discussion in narrative preceding on deionized water.

Any discussion of this article not published above will appear in December, 1961 issue.

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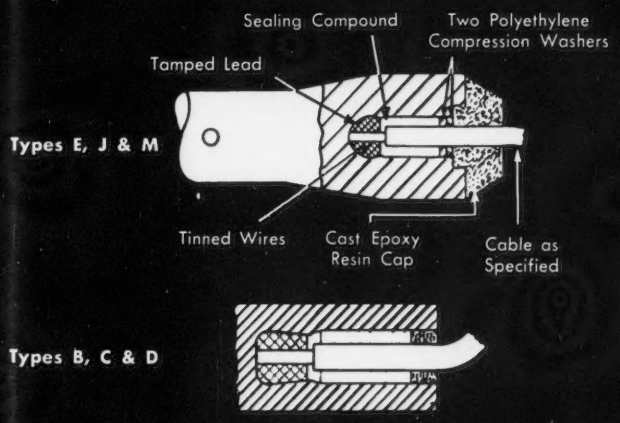

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G	2" x 9"	0.4	5	Ducts
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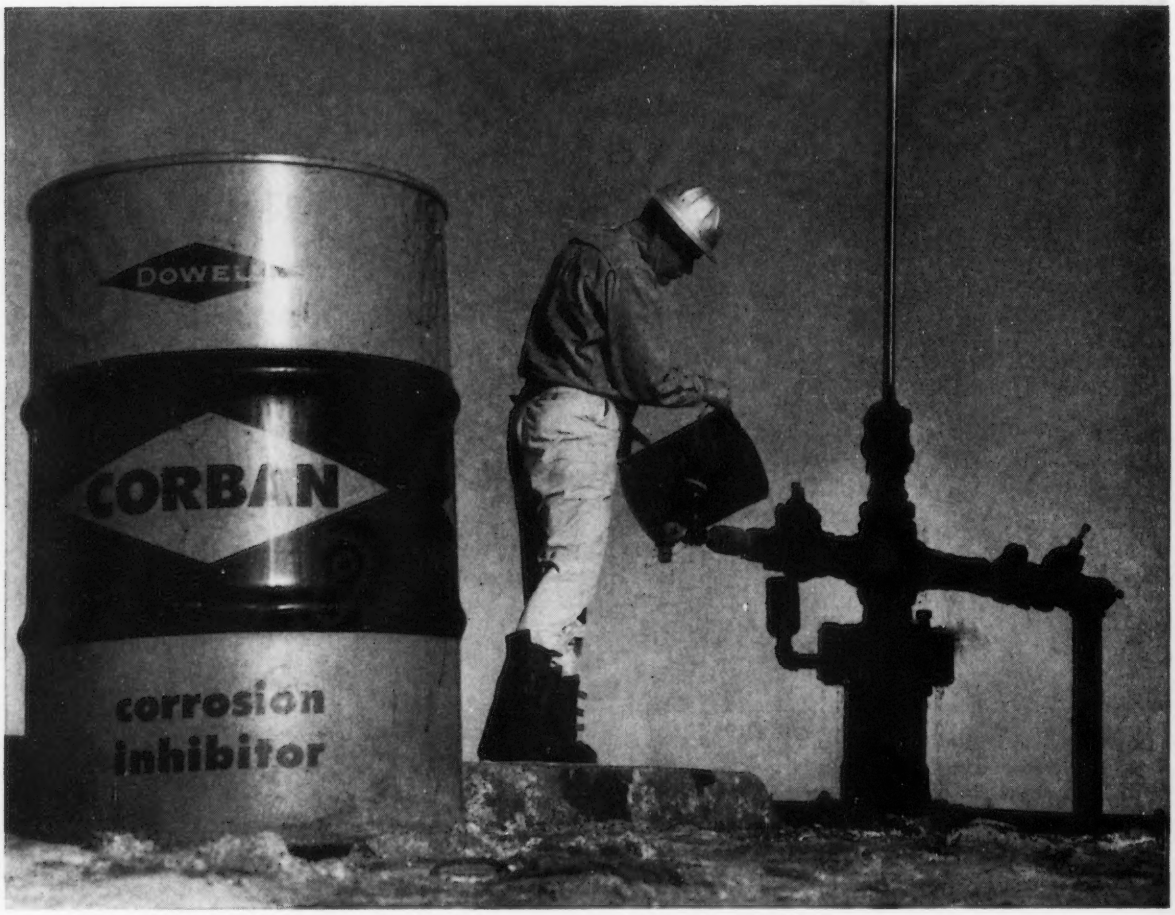

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